



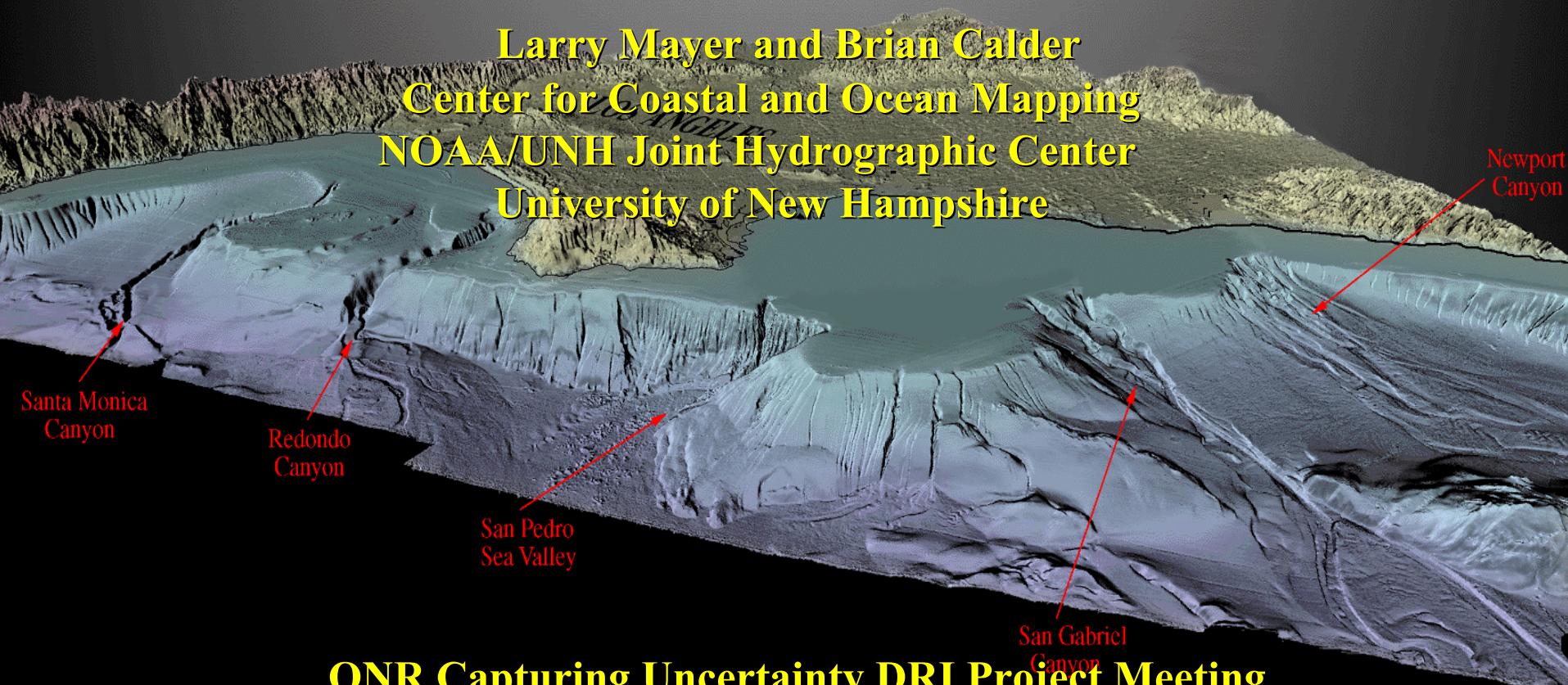
Mapping and Visualizing the Uncertainty of Multibeam Sonar Data

Larry Mayer and Brian Calder

Center for Coastal and Ocean Mapping

NOAA/UNH Joint Hydrographic Center

University of New Hampshire



ONR Capturing Uncertainty DRI Project Meeting



Center for Coastal and Ocean Mapping

Mandate: The development of innovative new “hydrographic” & ocean mapping technologies and approaches

Hydrography –mapping in support of safe navigation – implies liability – requires uncertainty management

Projects:

- ***Remote seafloor characterization***
- ***Data Visualization and Fusion***
- ***New approaches to multibeam sonar data processing and error and uncertainty modeling***



Single Beam Sonar

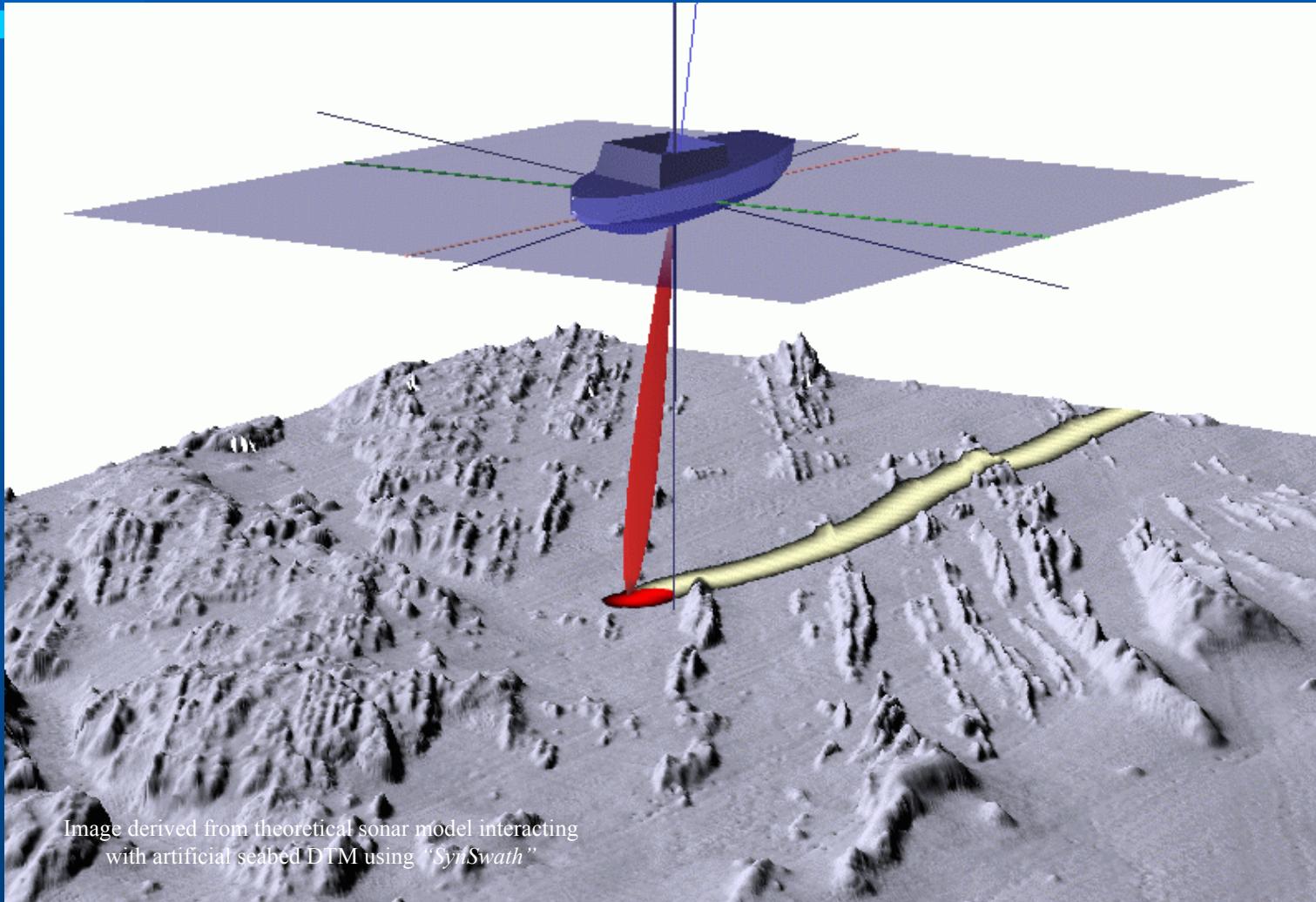


Image derived from theoretical sonar model interacting
with artificial seabed DTM using "SynSwath"



Multibeam Sonar

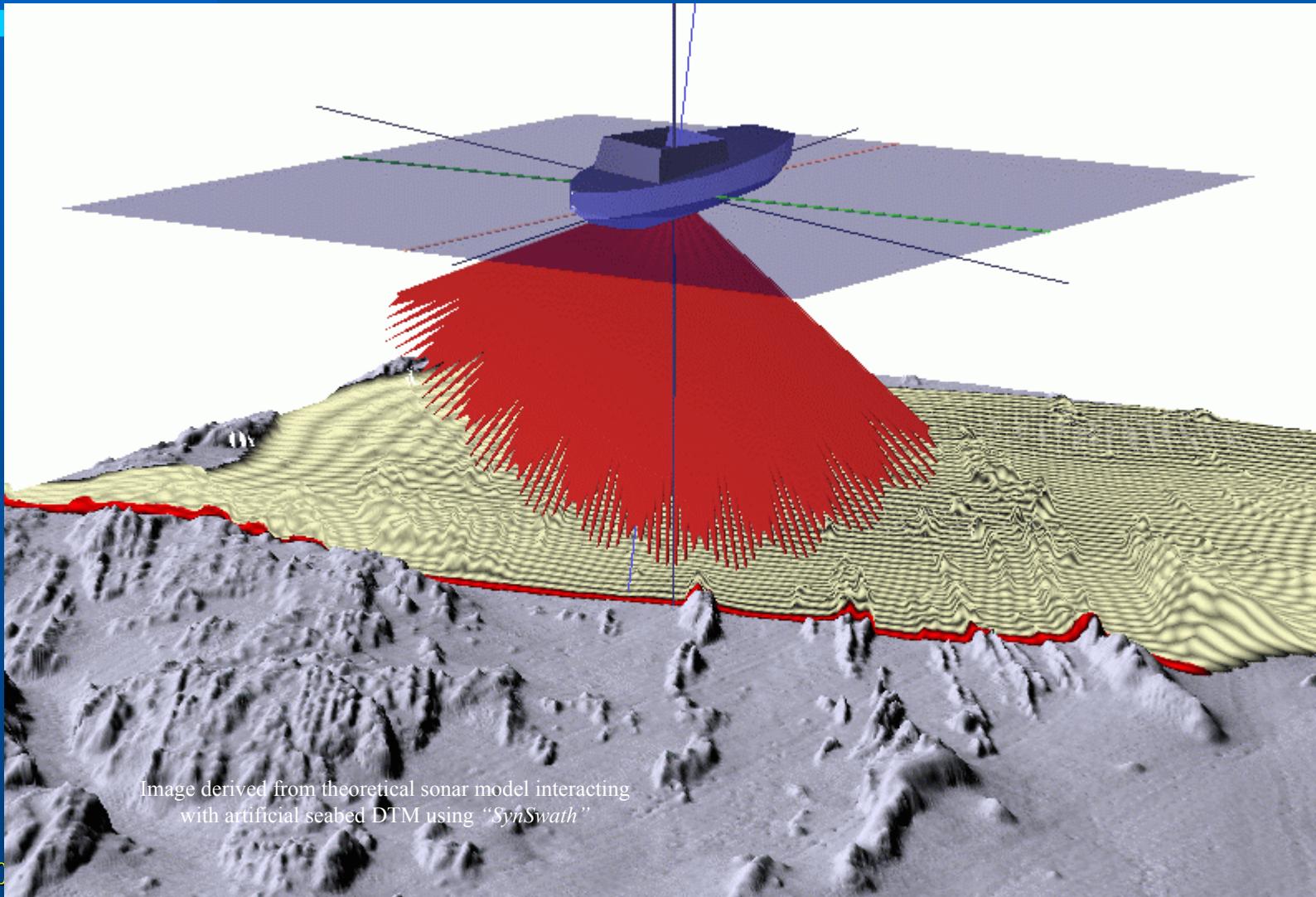
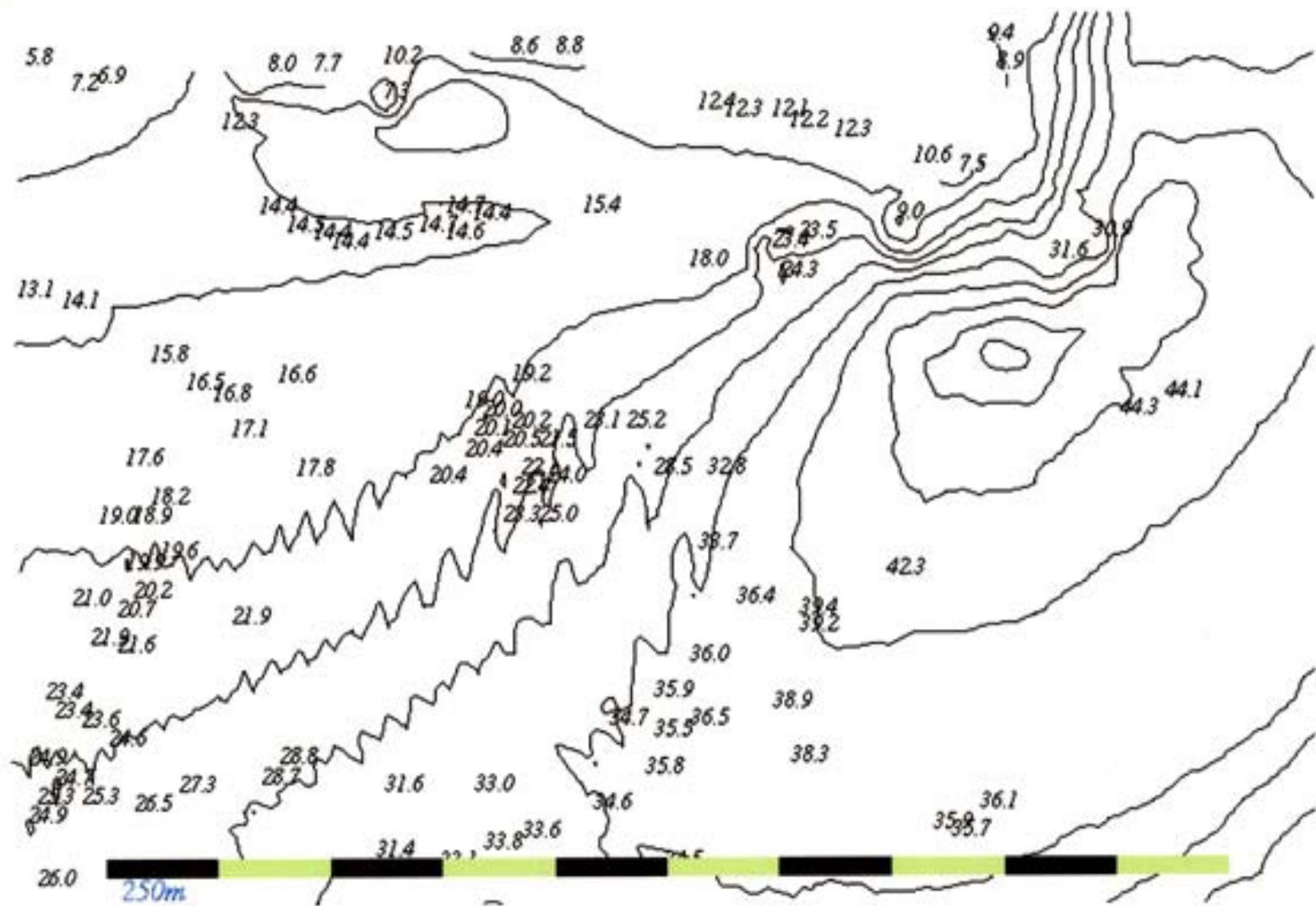


Image derived from theoretical sonar model interacting
with artificial seabed DTM using "SynSwath"

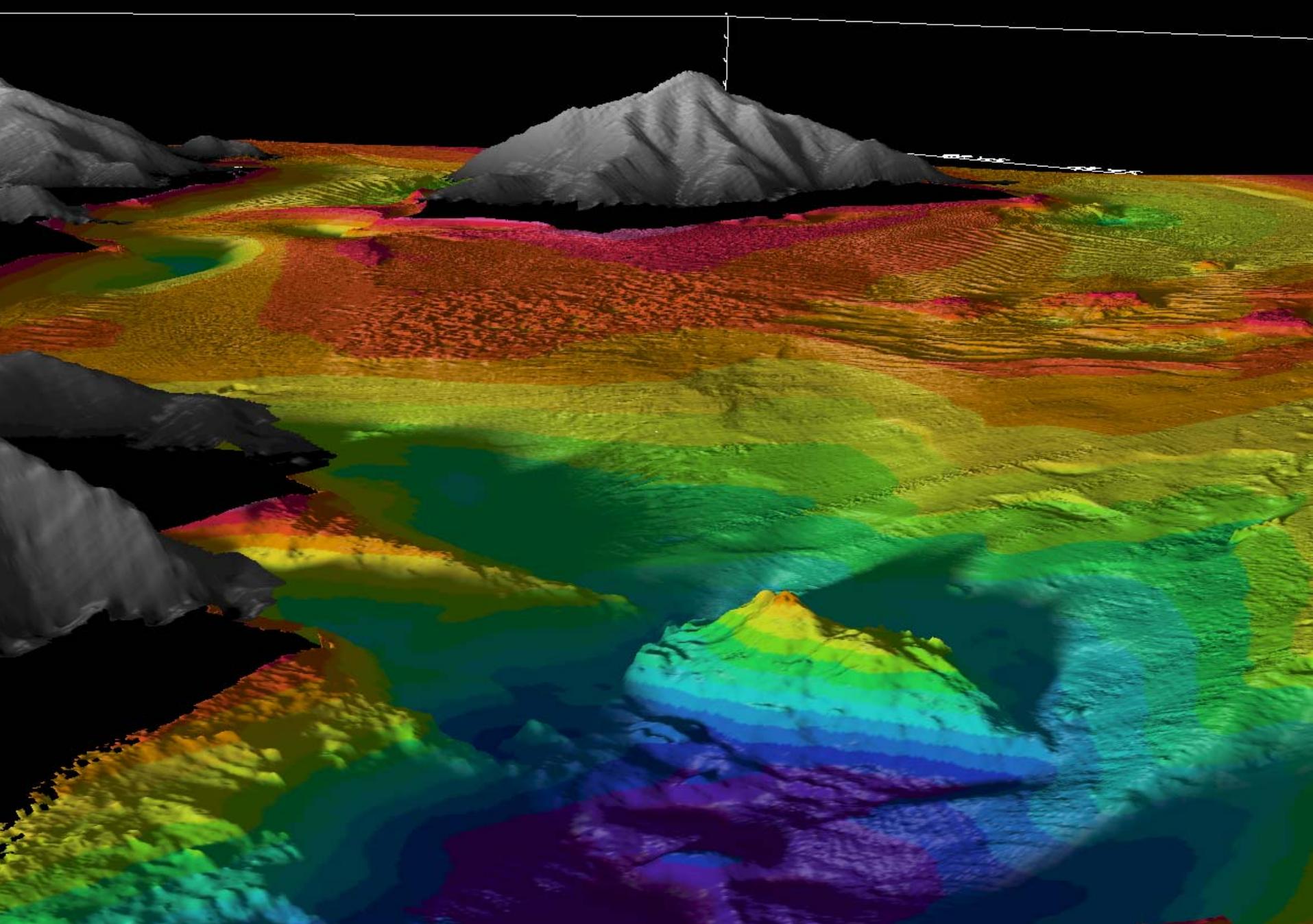


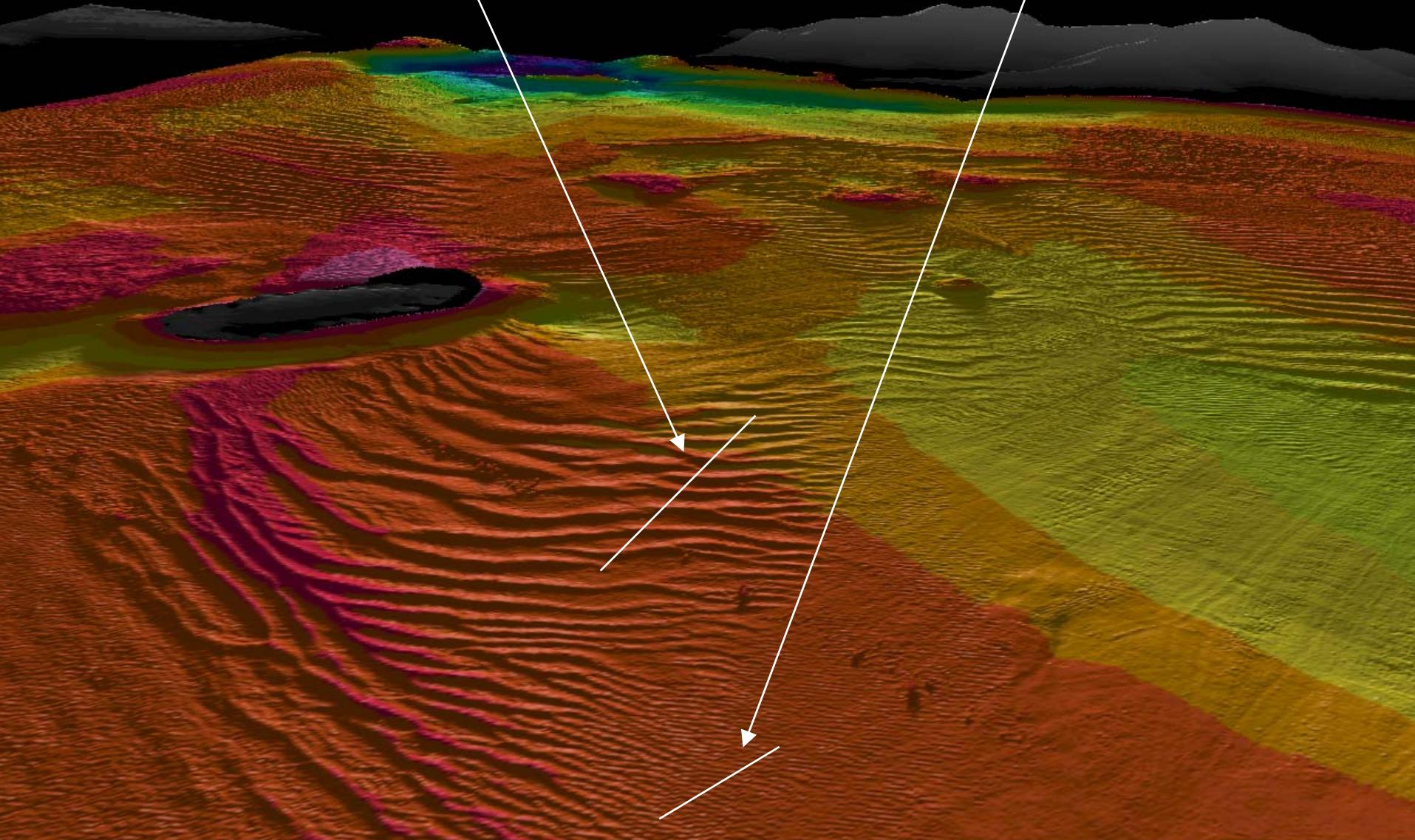
C&C Tech., San Francisco Bay: EM1000 8 knots

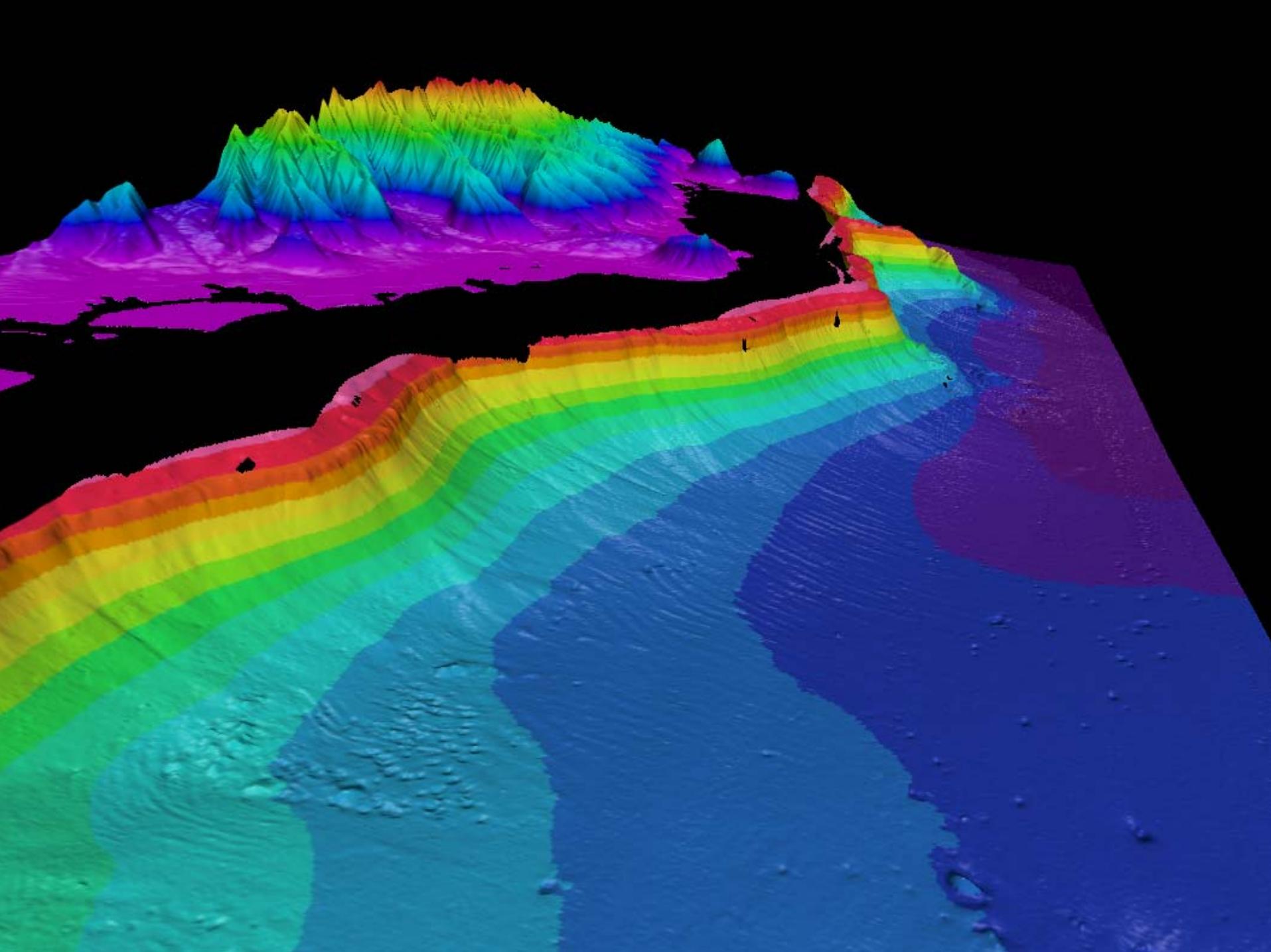


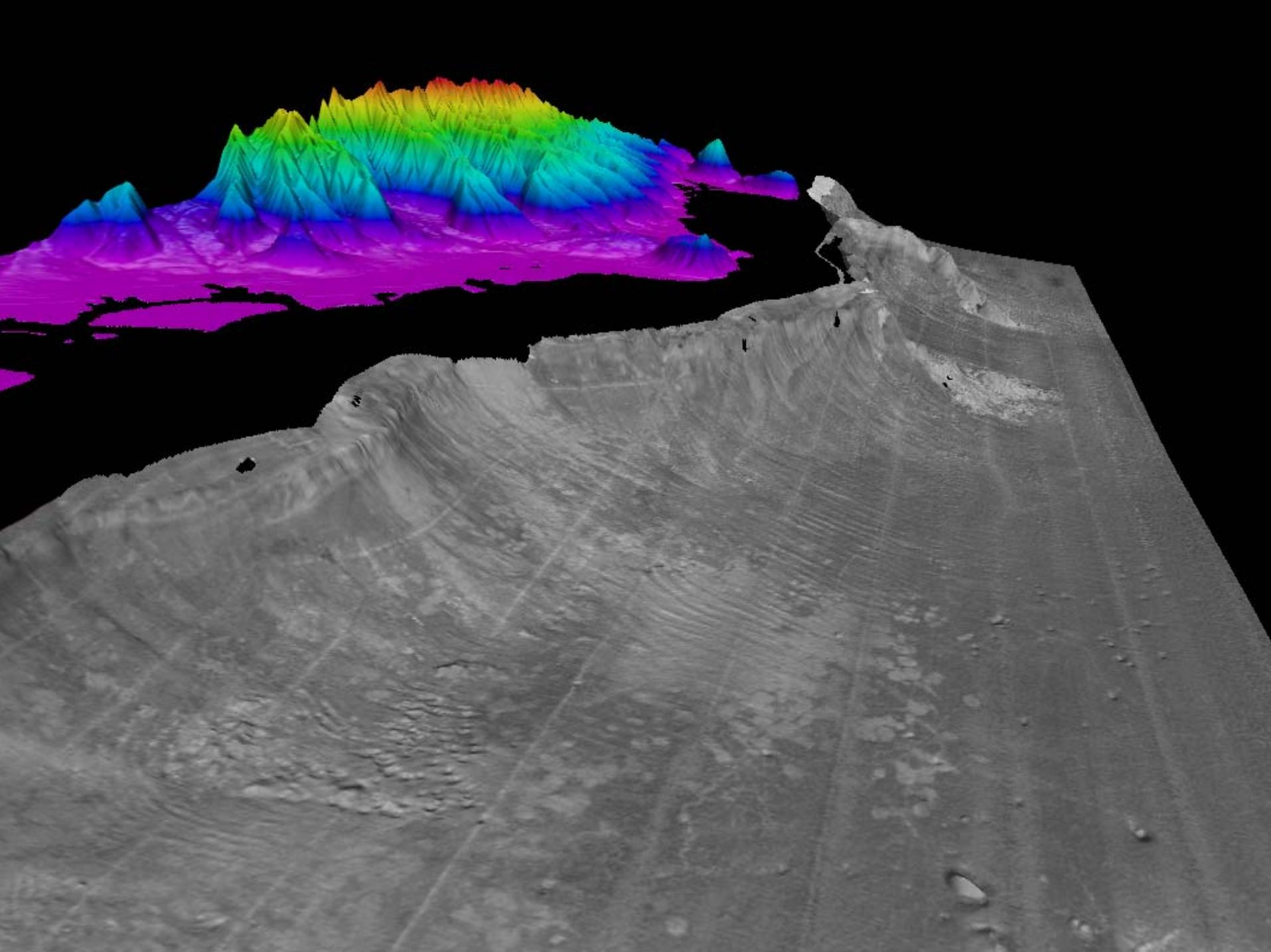
Processed using **OMG/UNB SwathEd**

Data courtesy of: USGS(WR) Jim Gardner







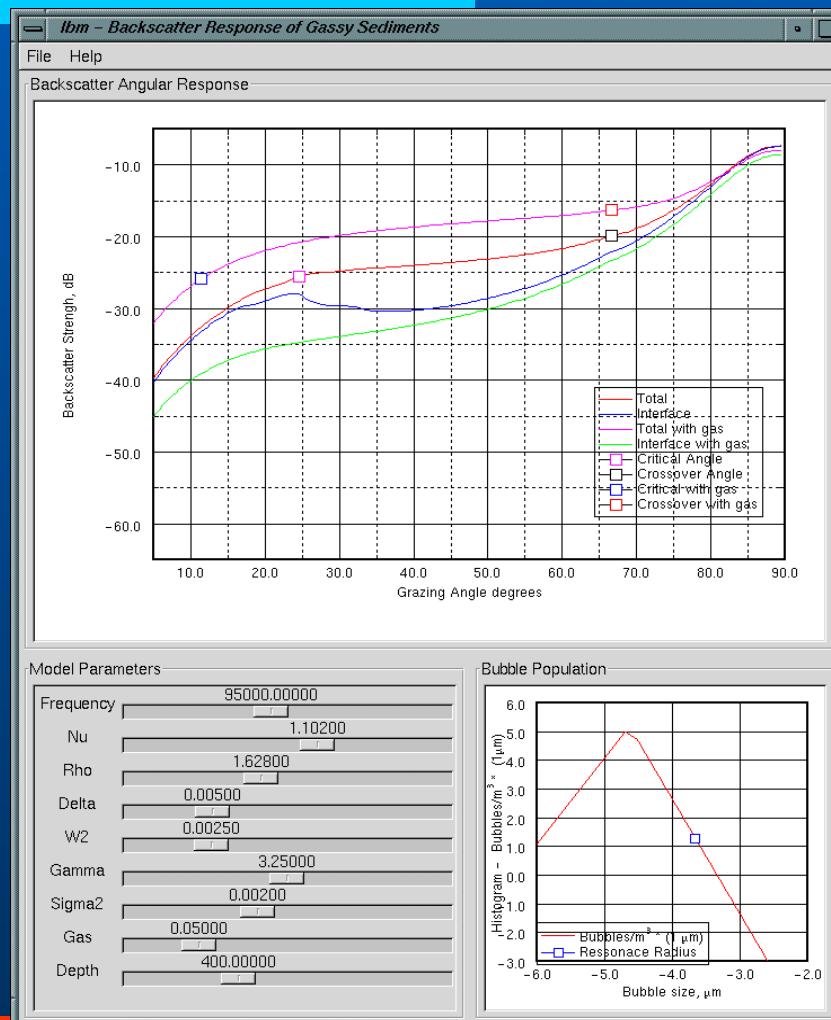




Seafloor Characterization

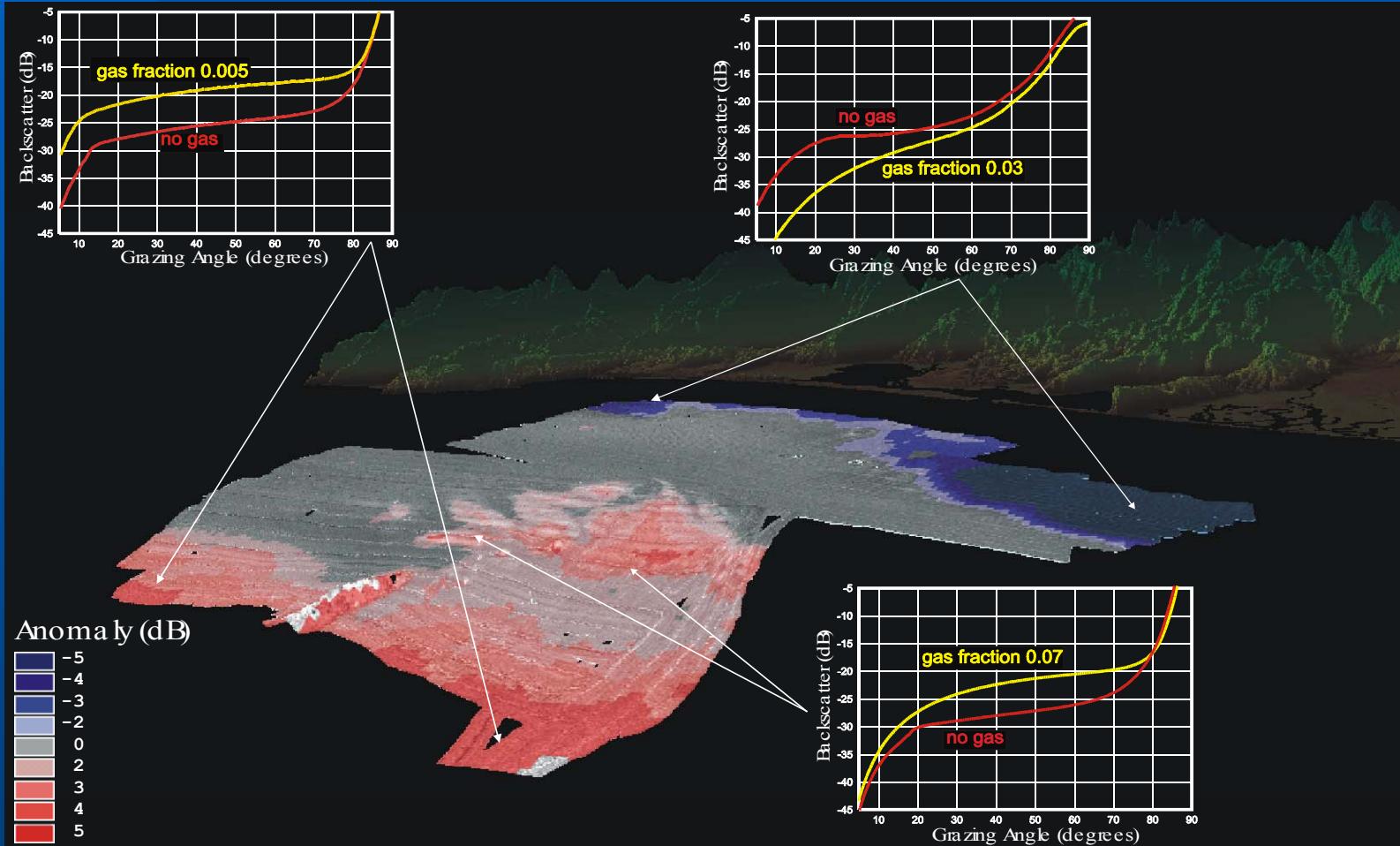


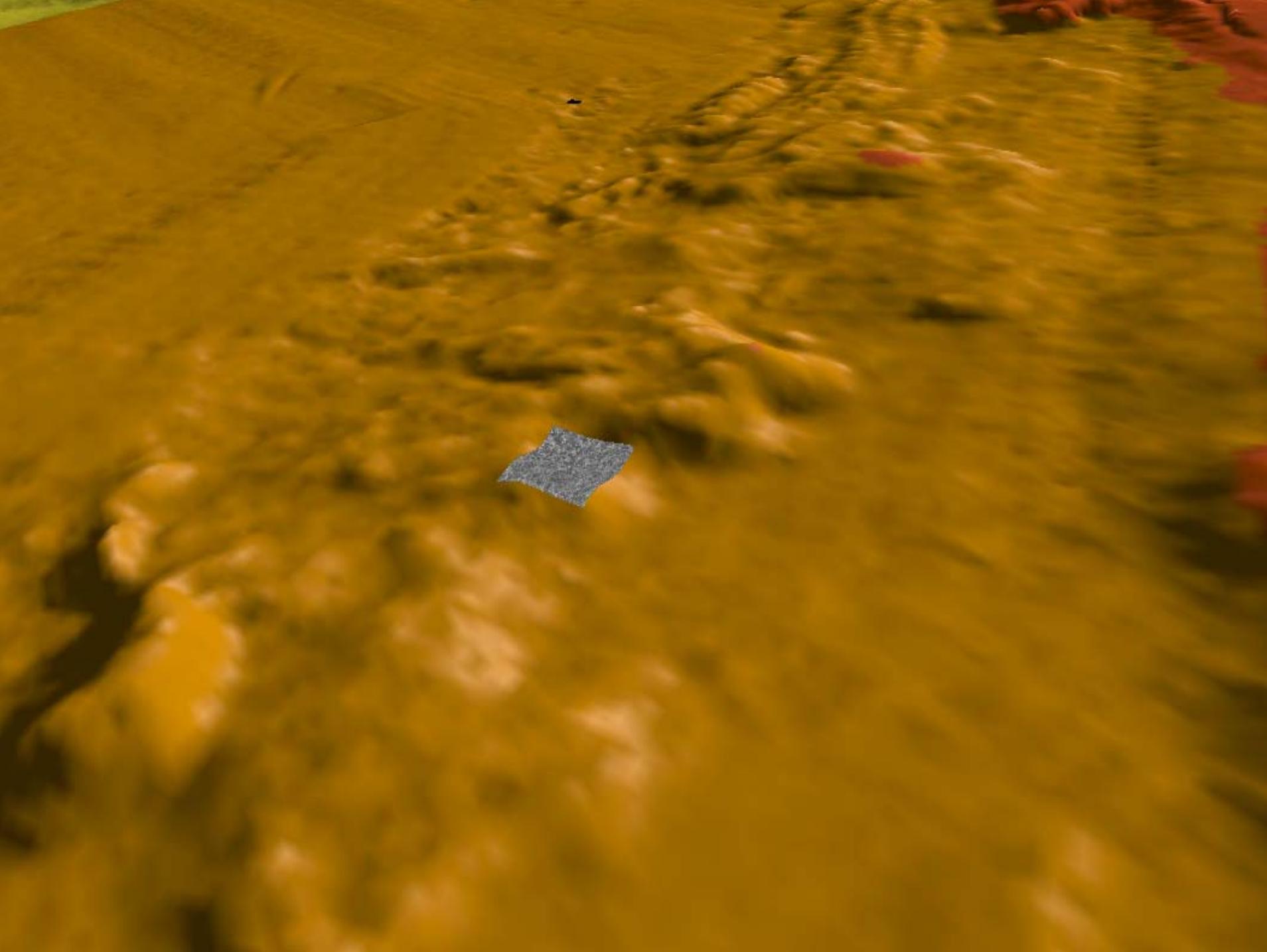
Extension of Jackson Model to include effect of gas on backscatter as a function of angle of incidence



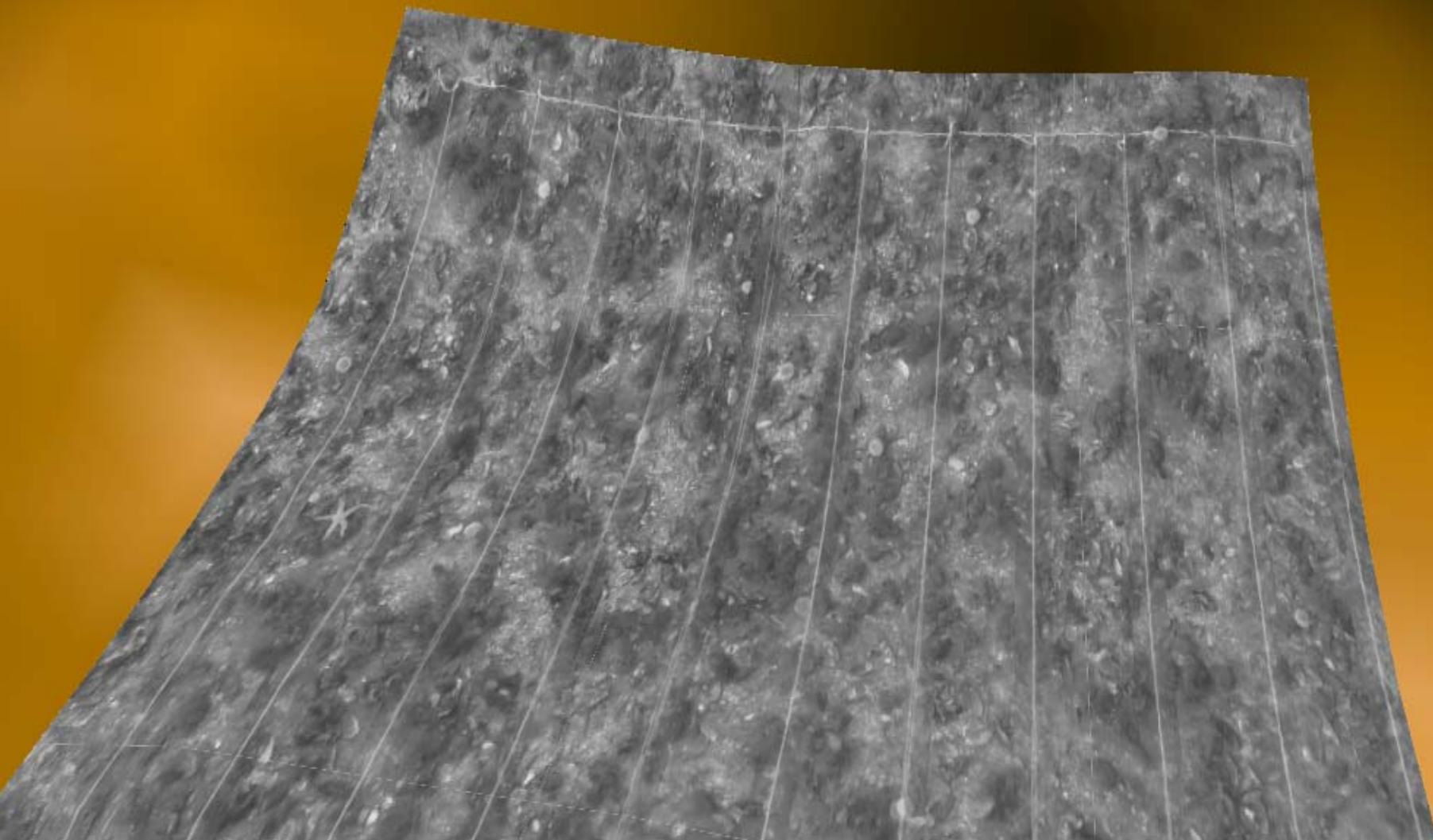


The extraction of gas content in surficial sediments from multibeam sonar data



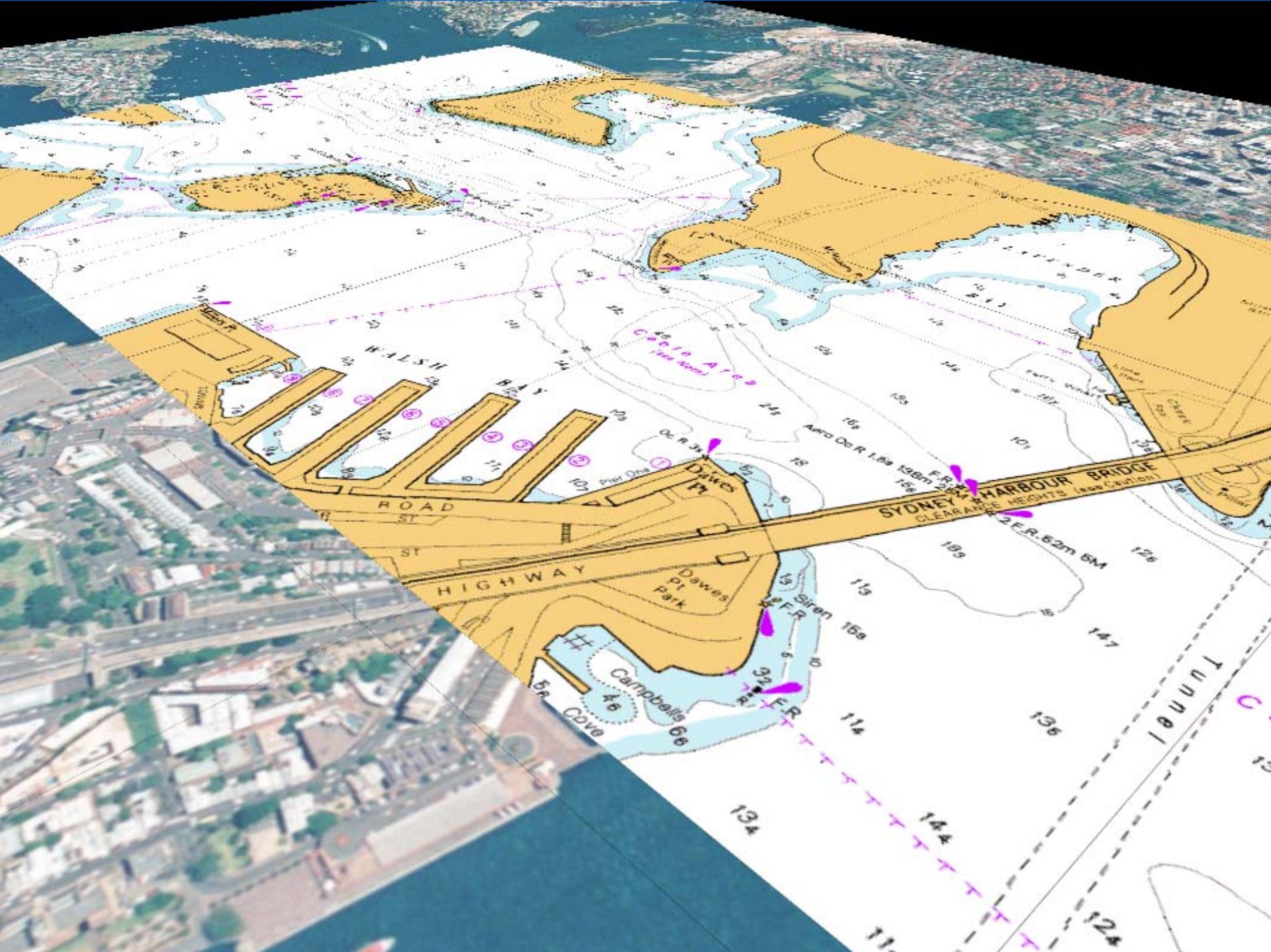


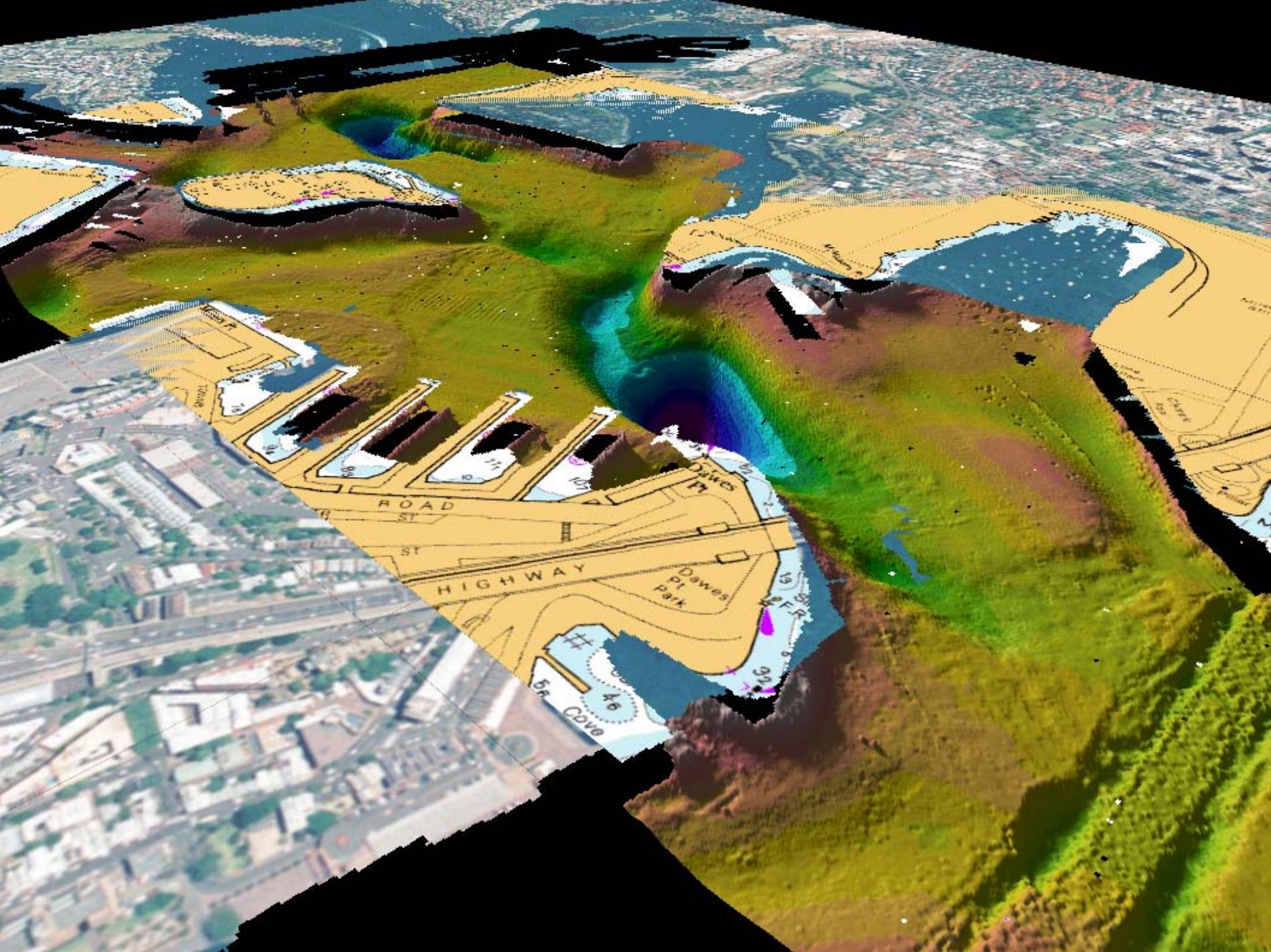
Would be even better with laser line scanner data!

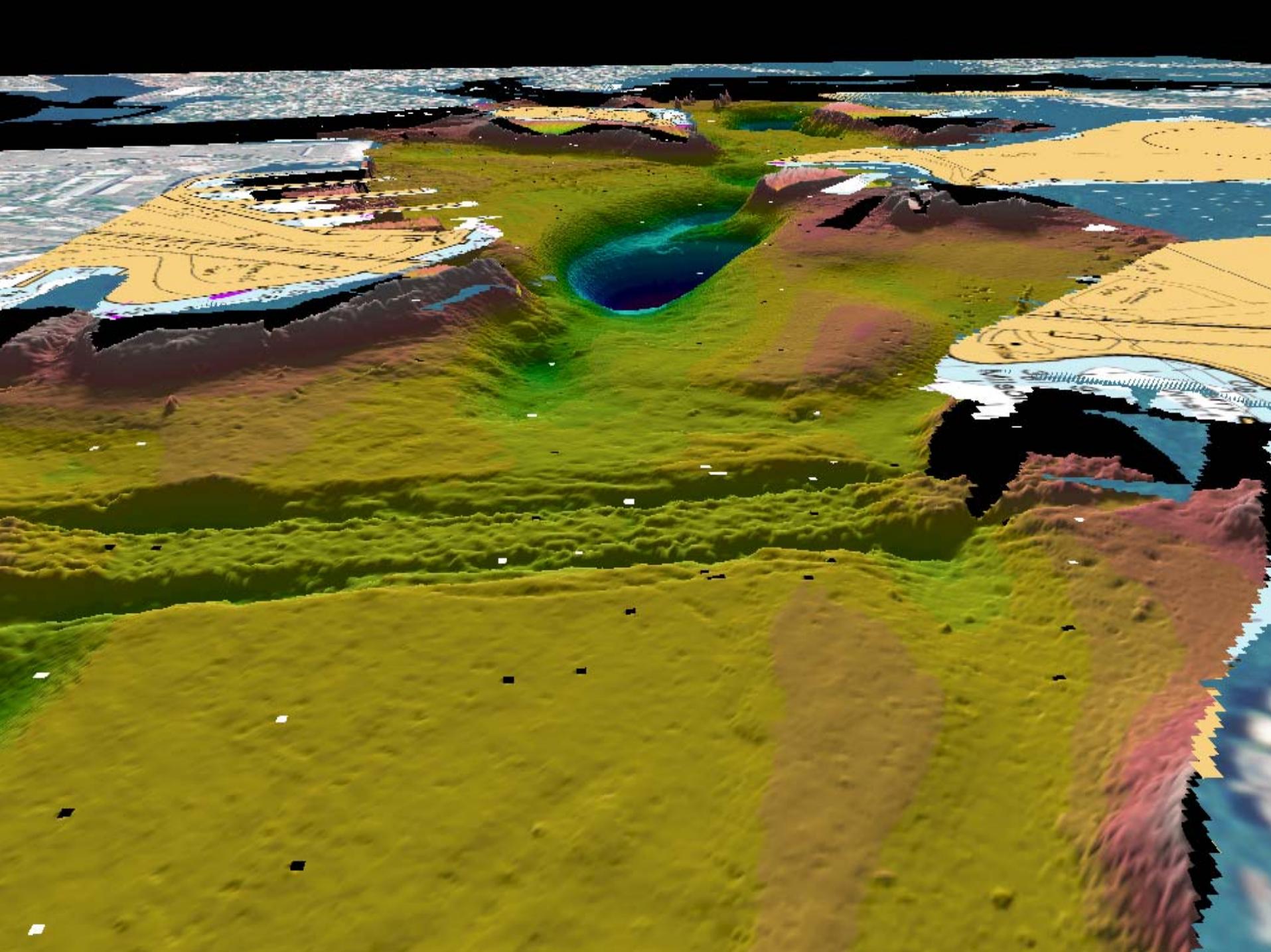


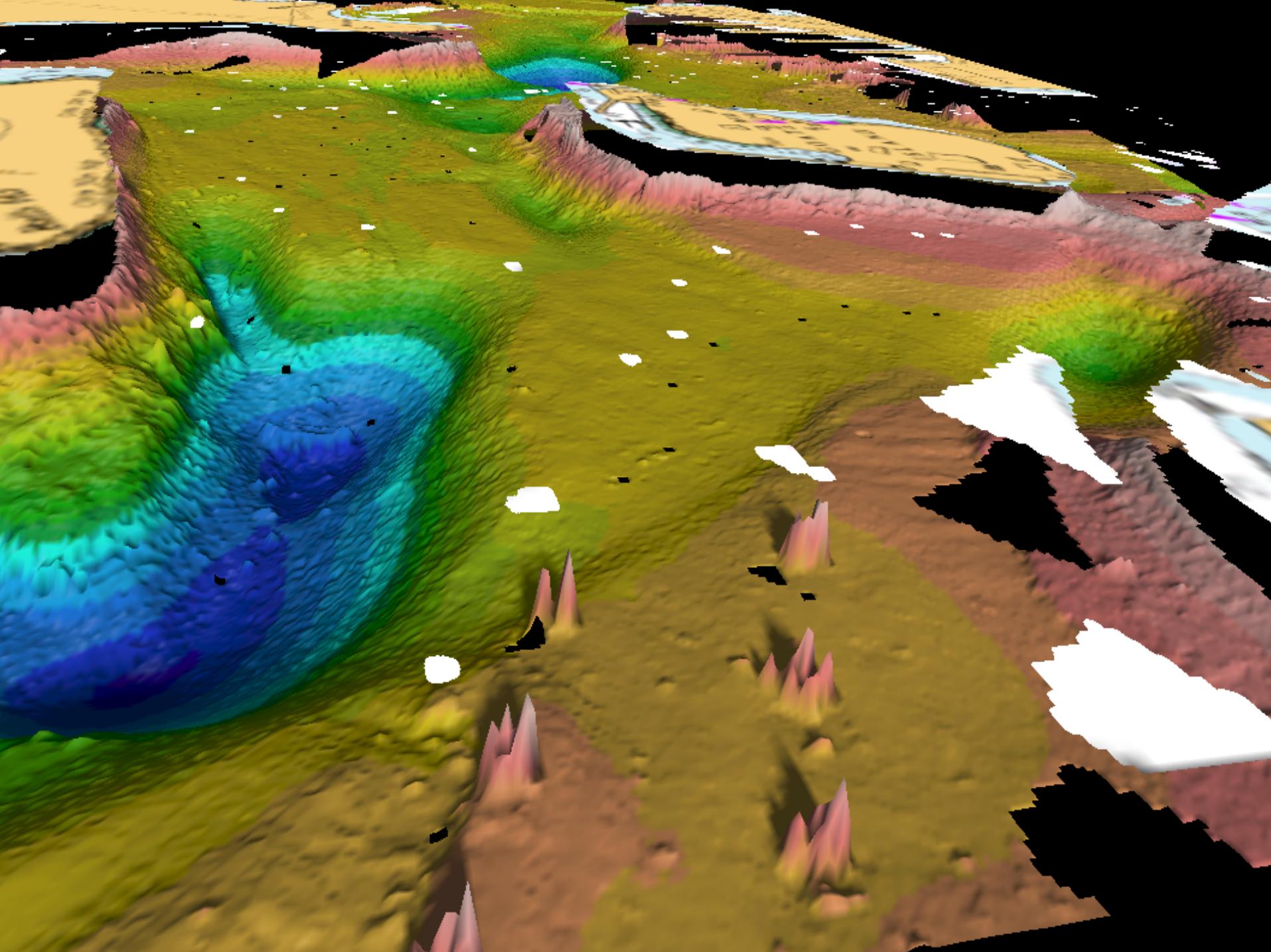
Data Fusion

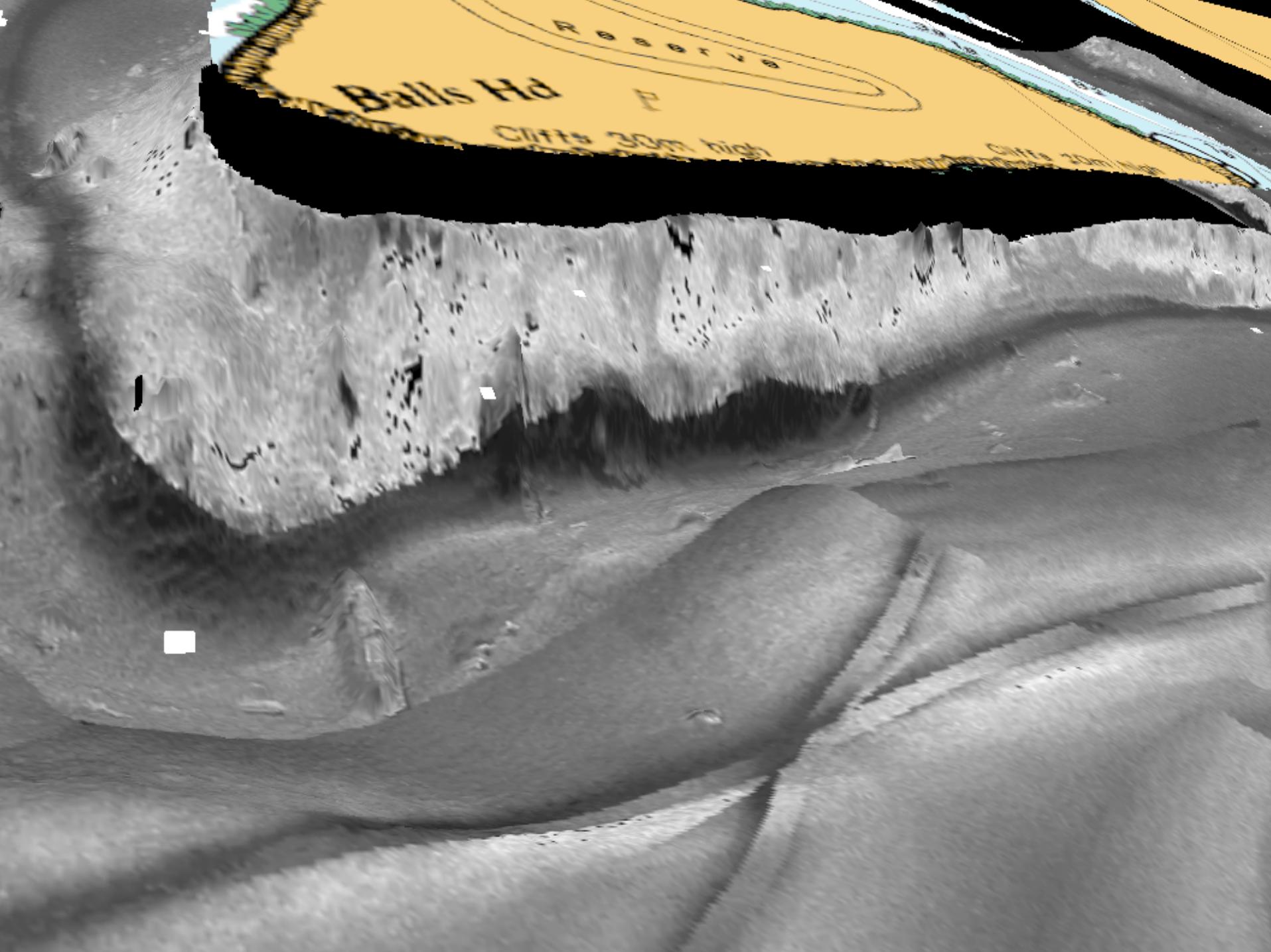












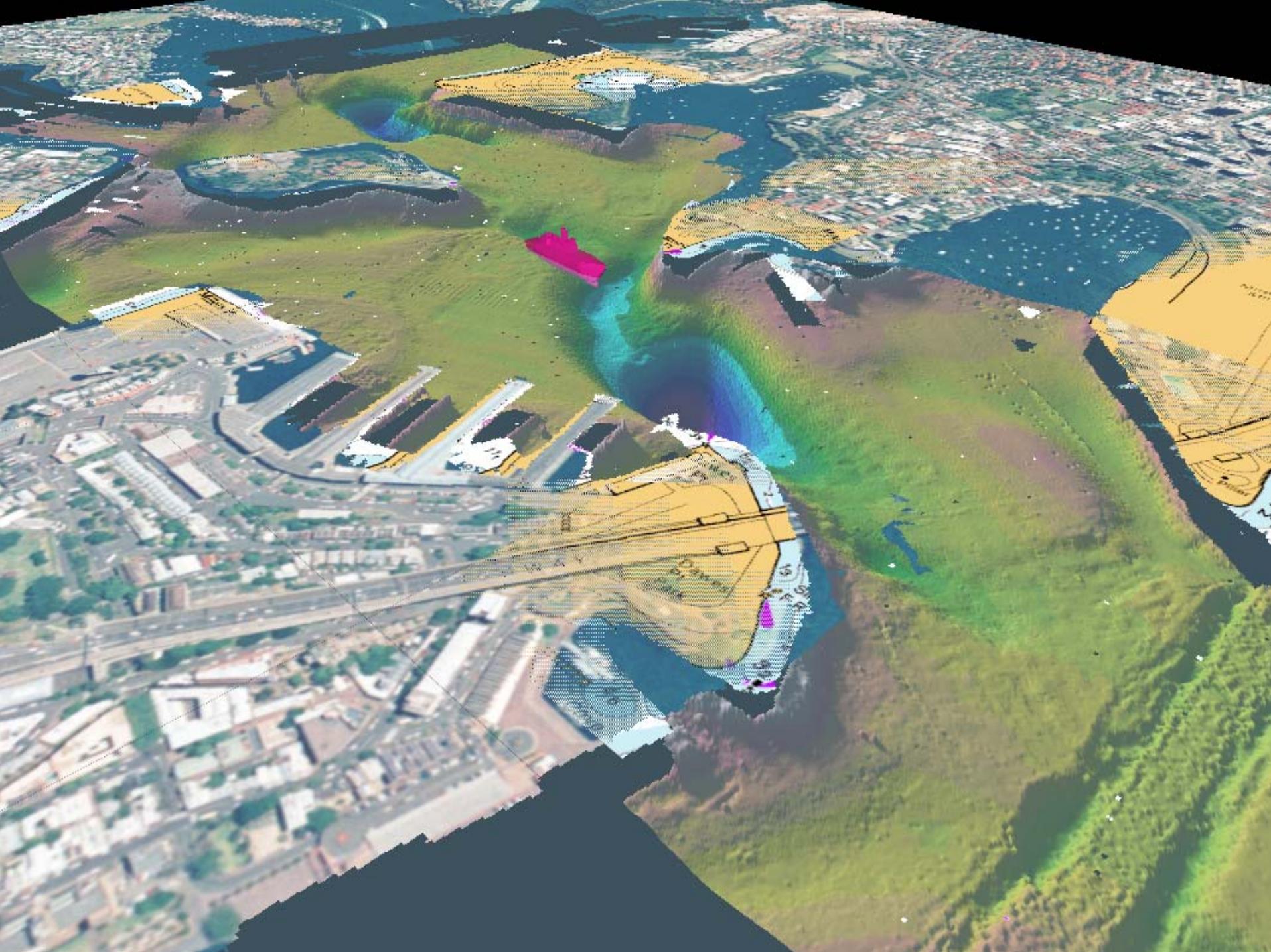
Balls Hd

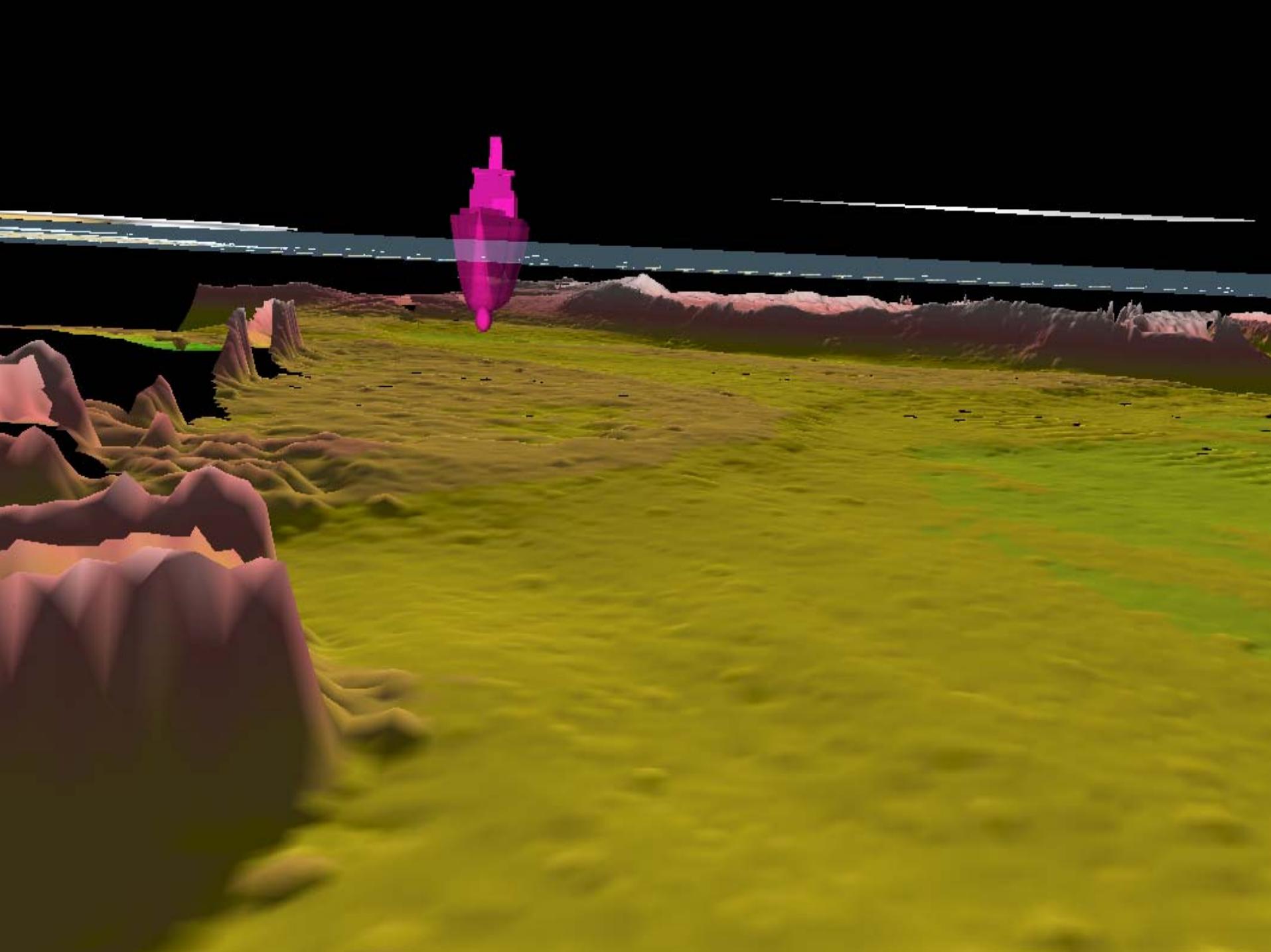
P

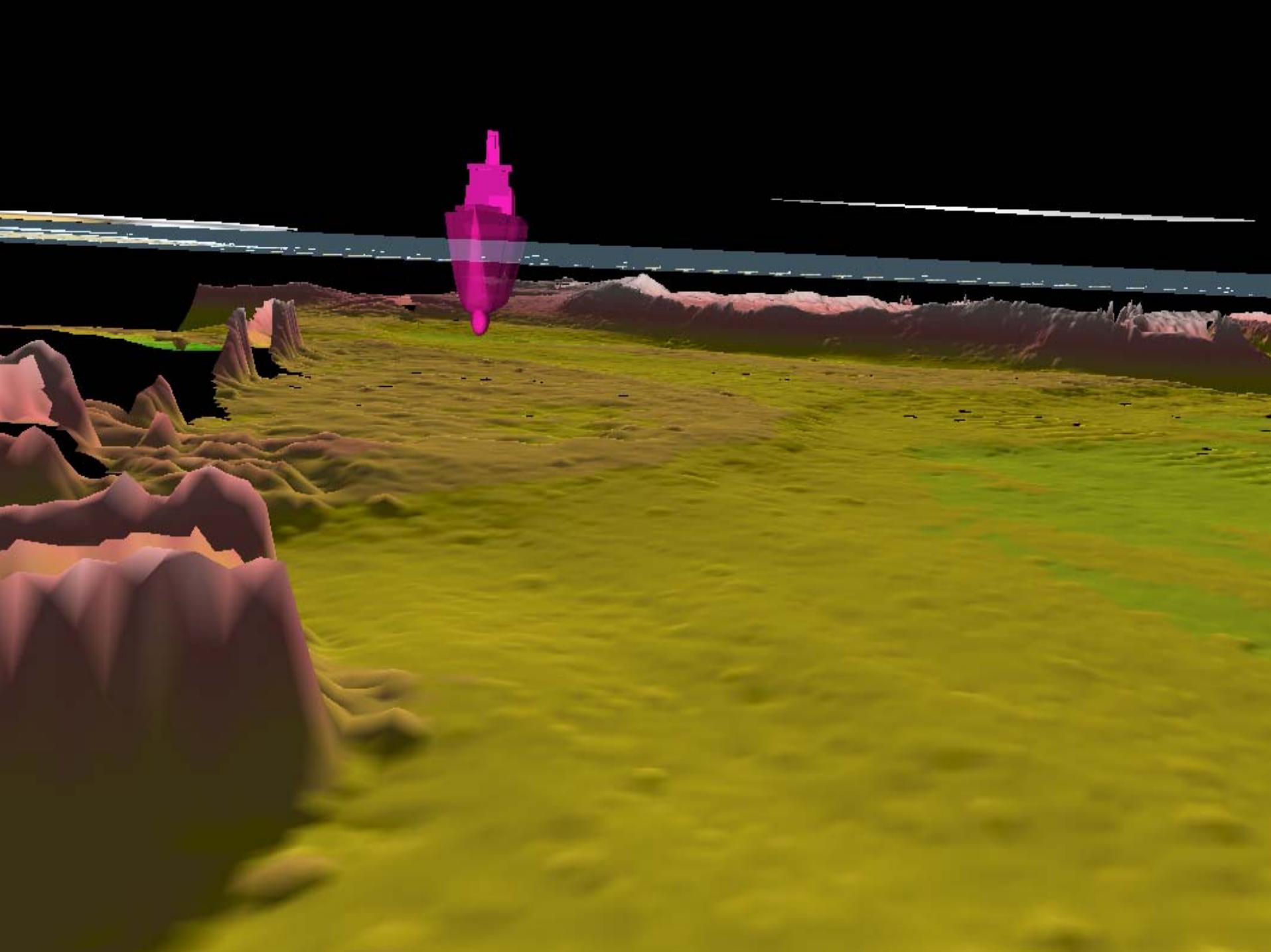
Reserve

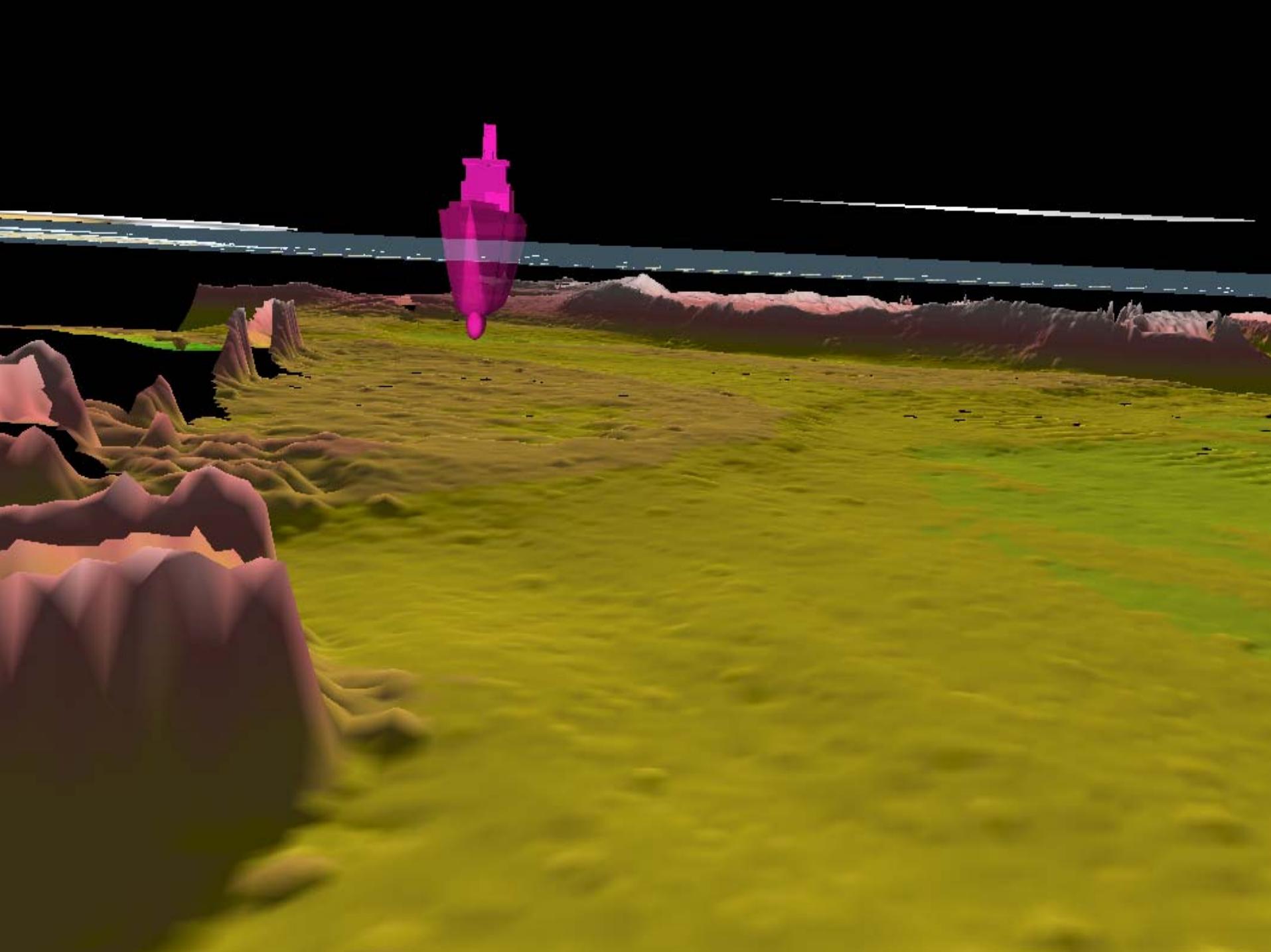
Cliffs 30m high

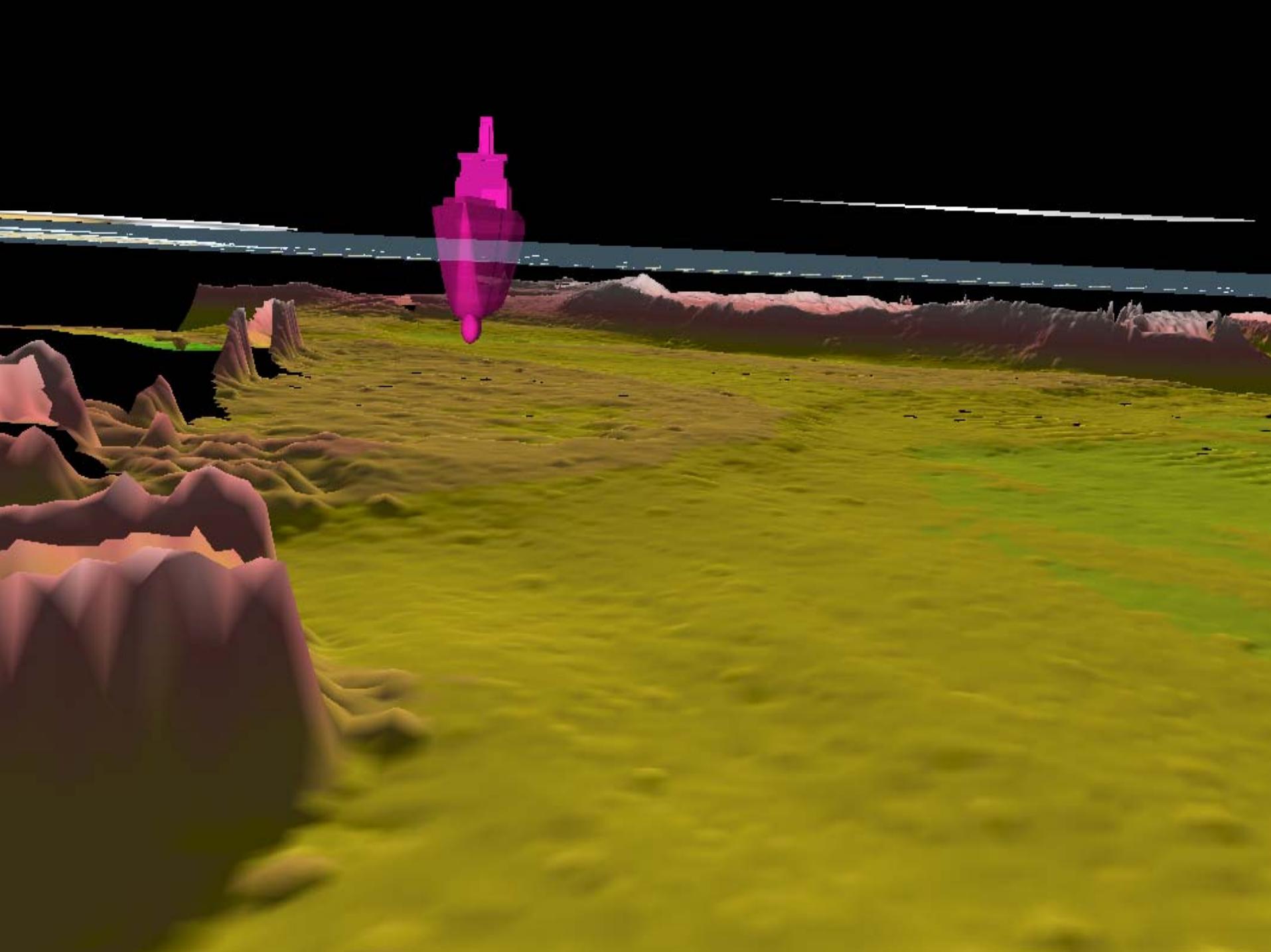
Cliffs 30m high

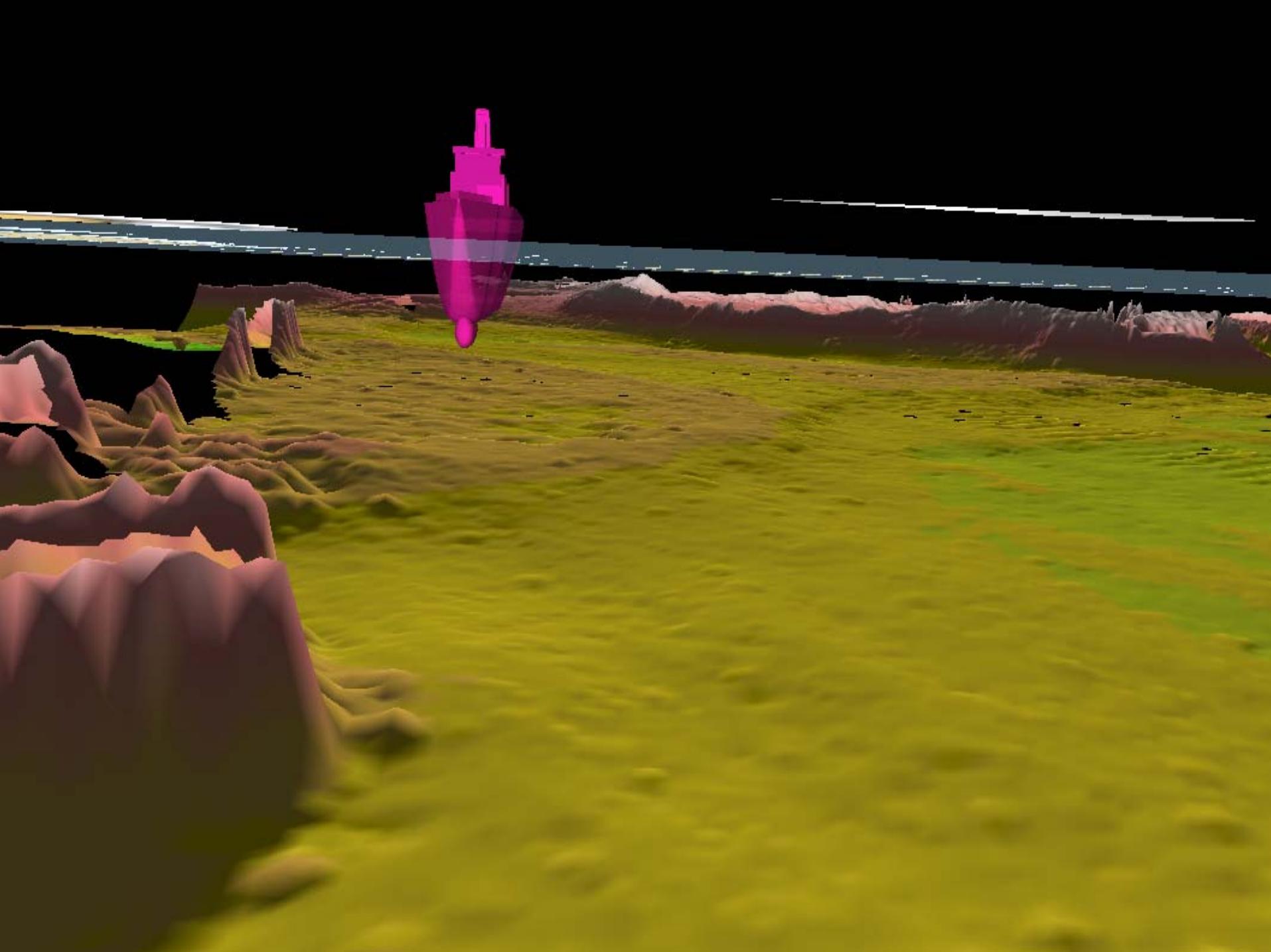


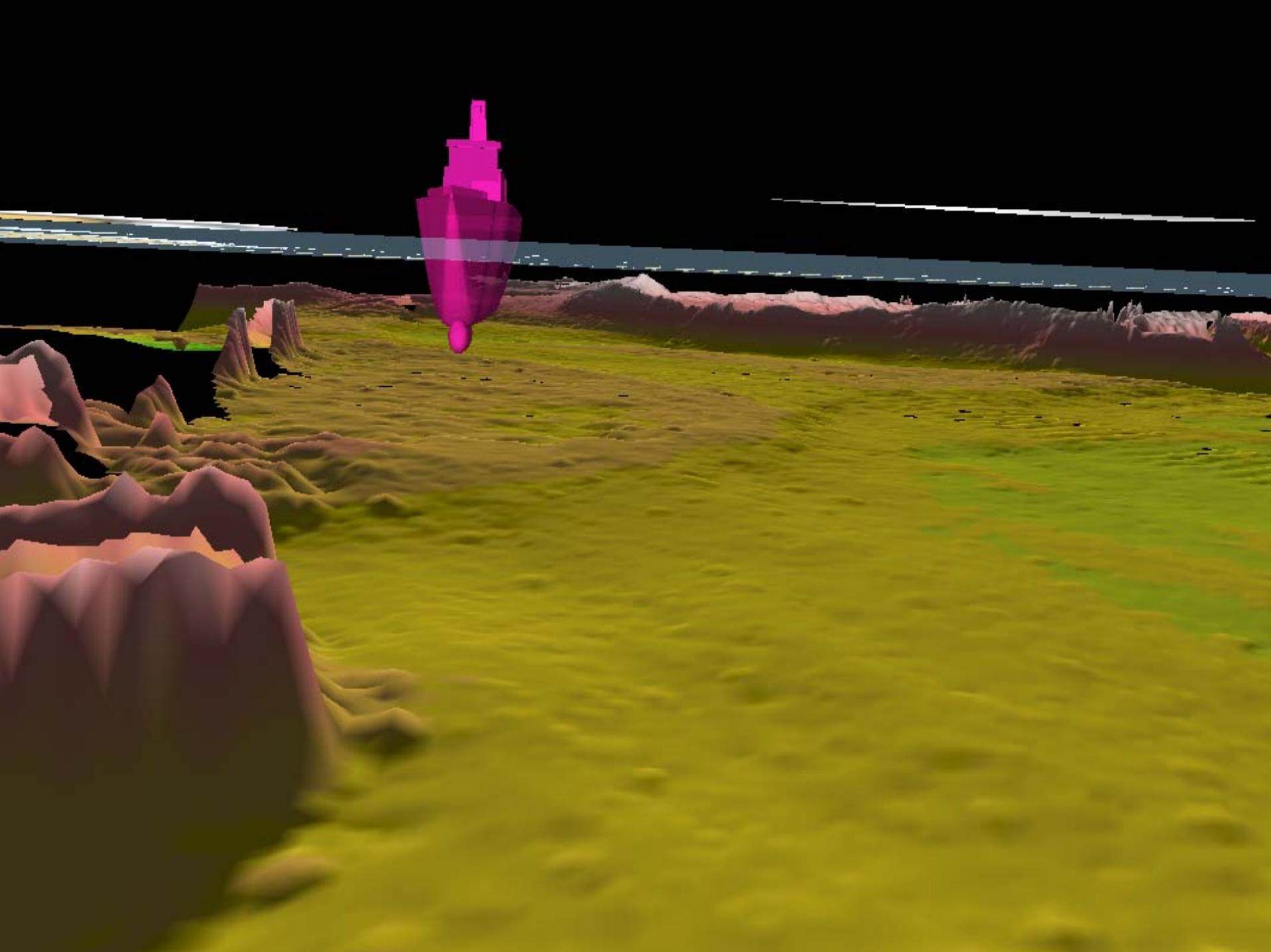


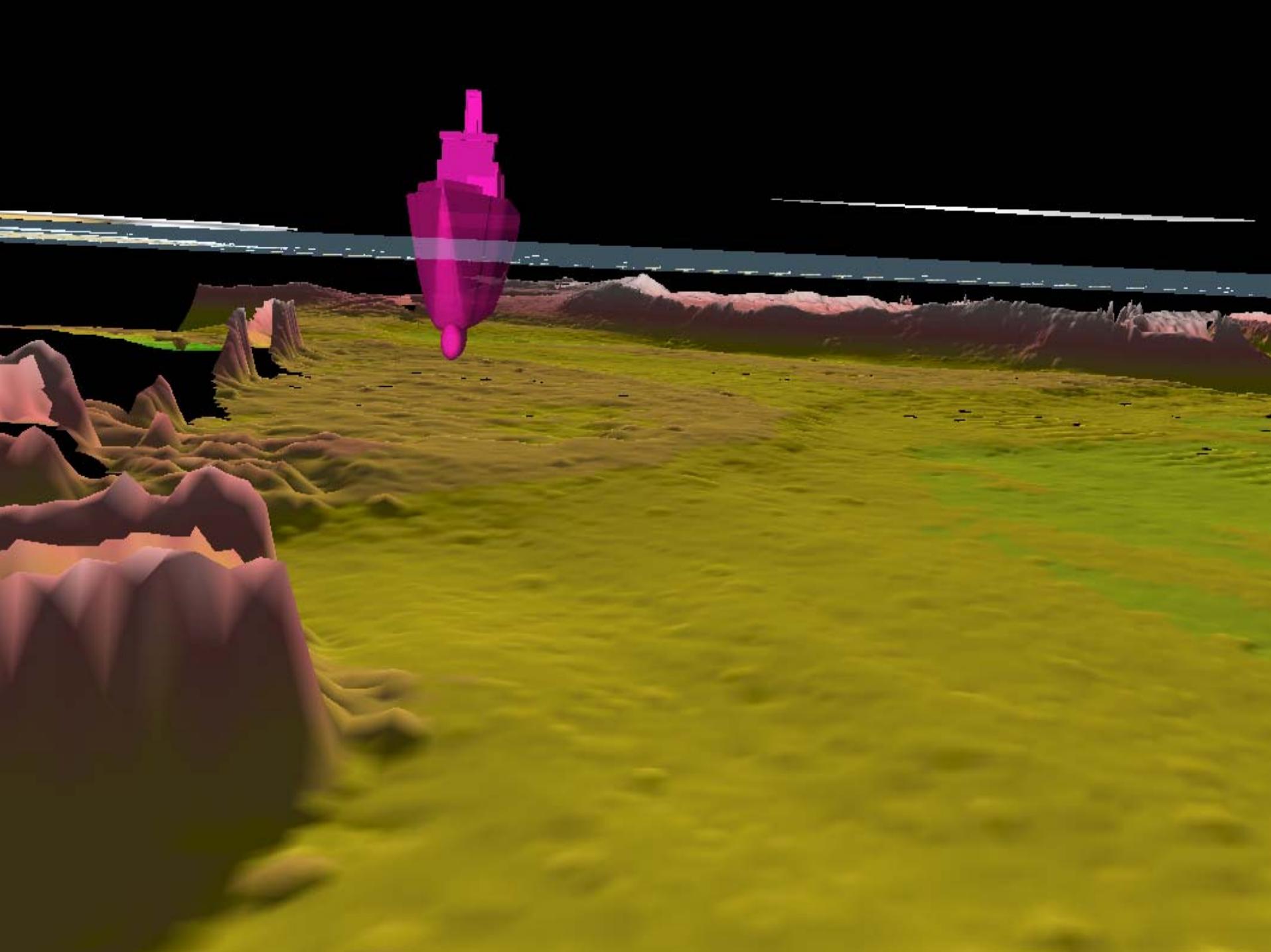


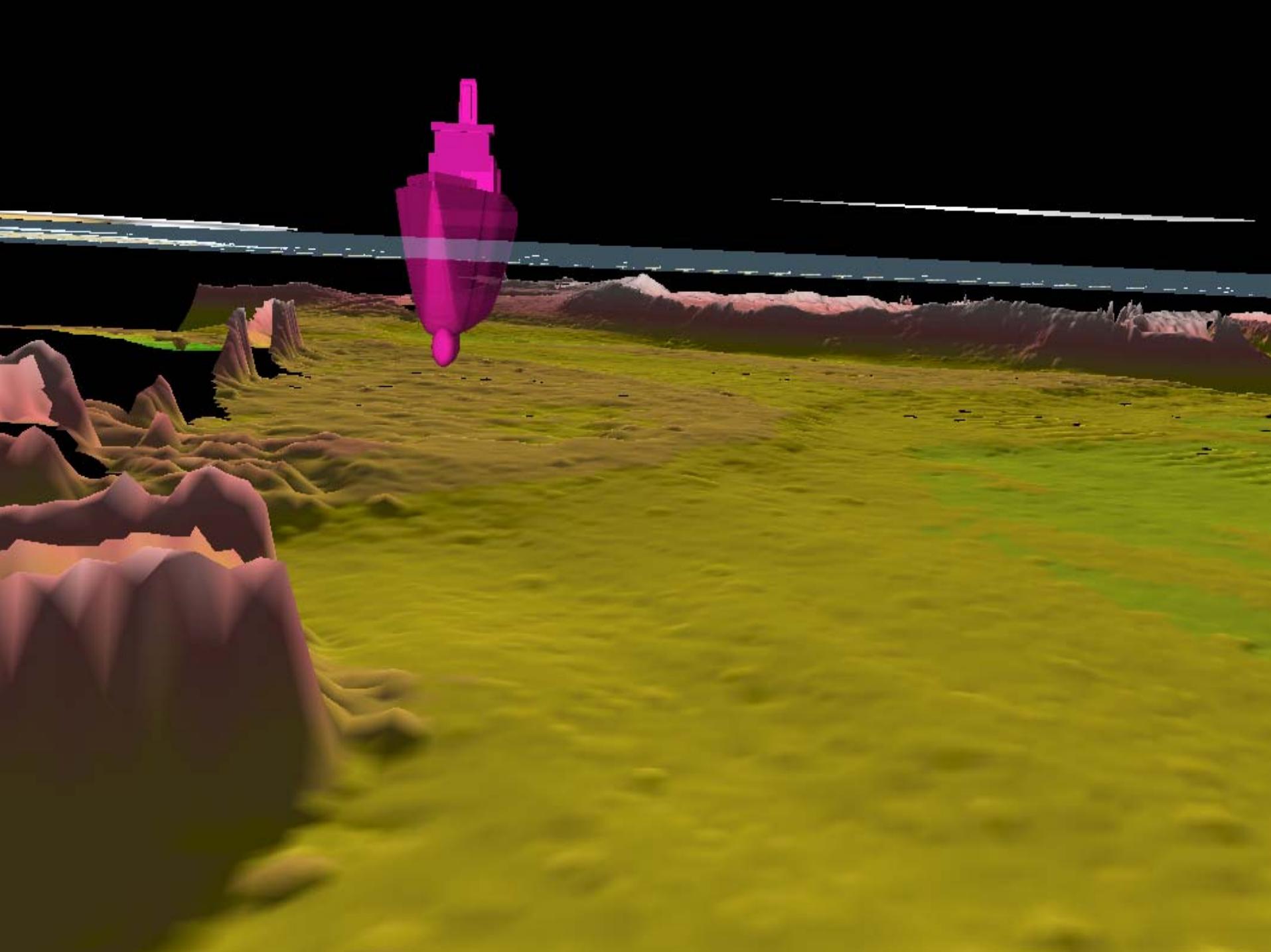


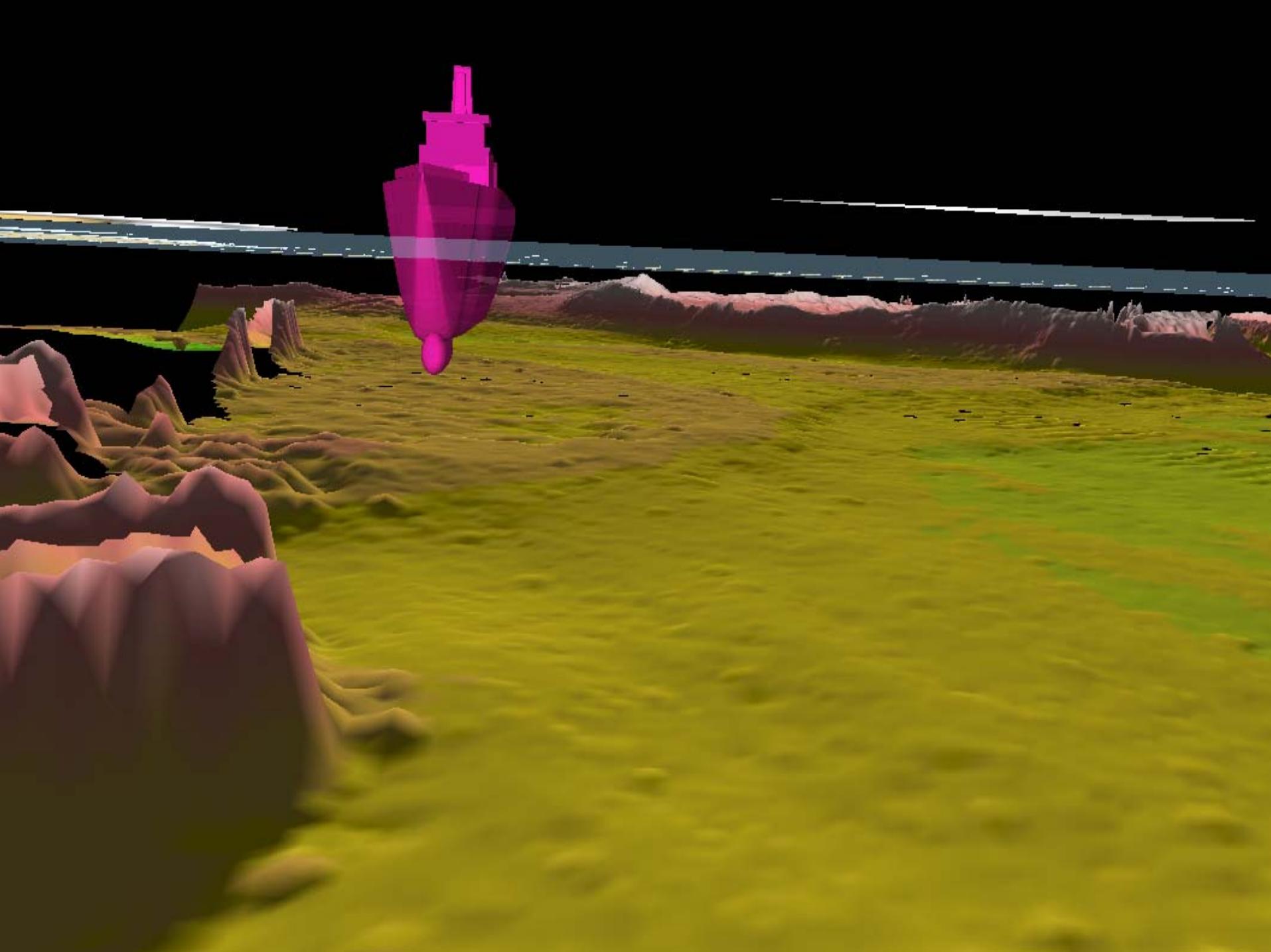


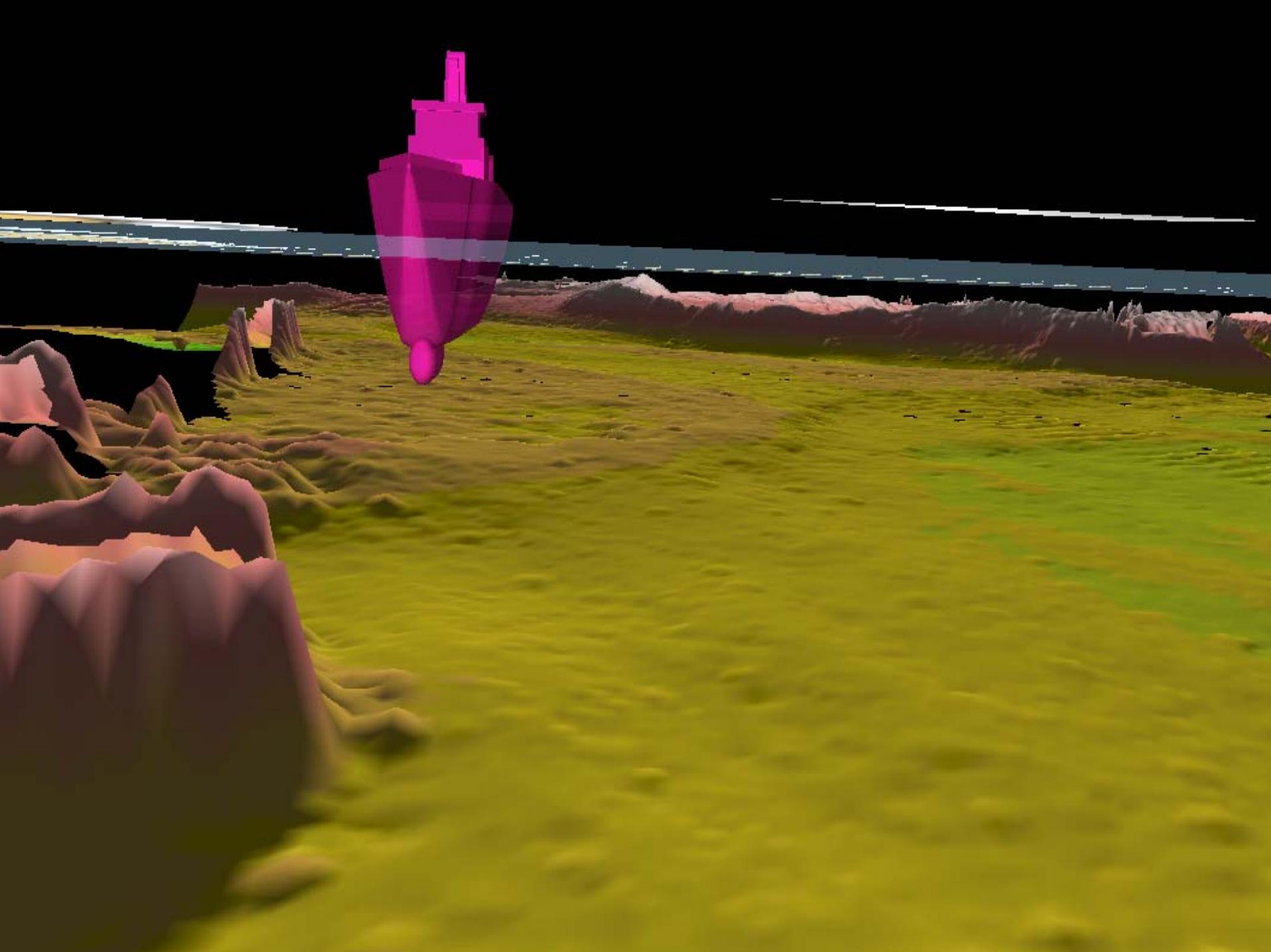


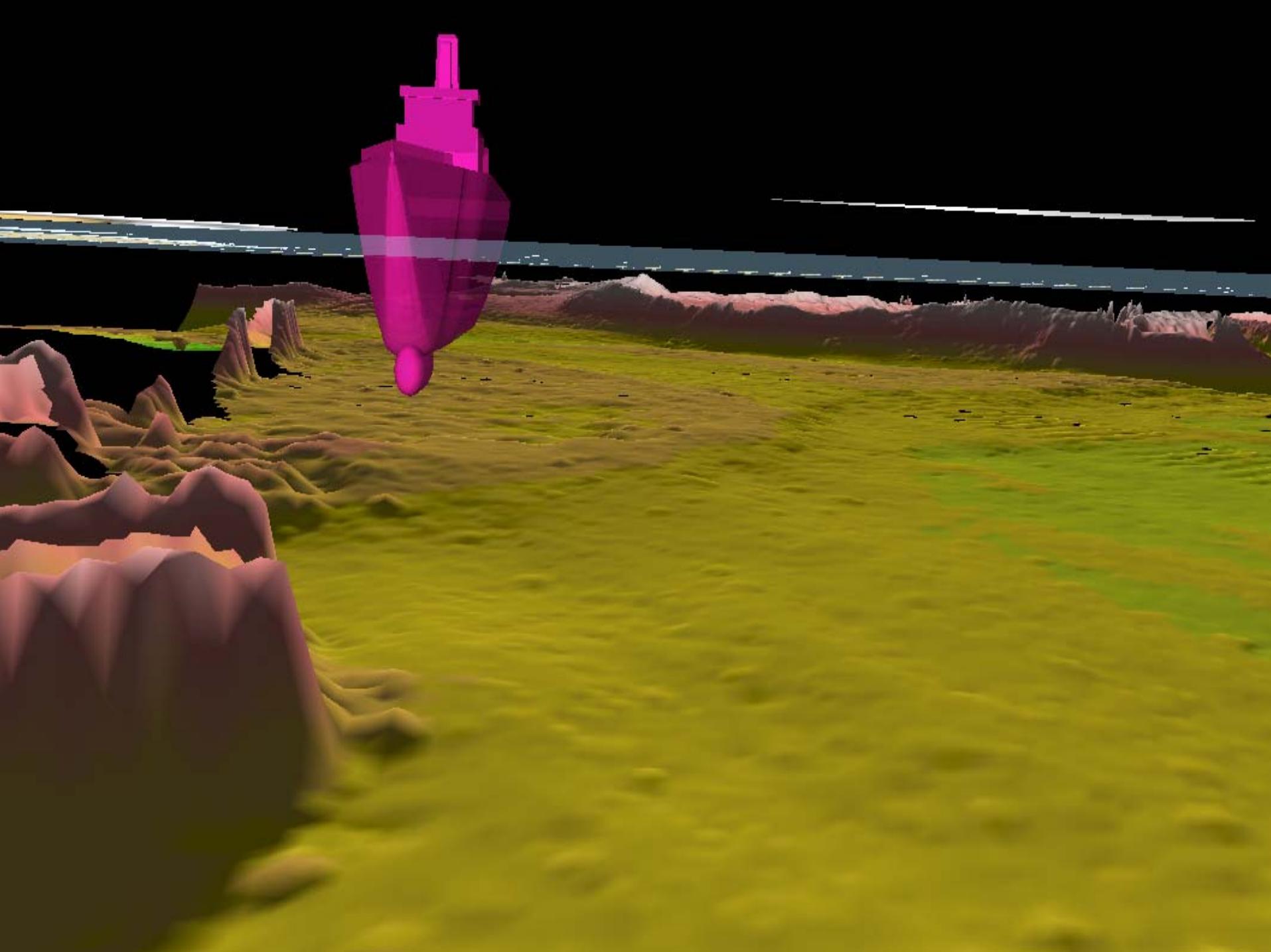


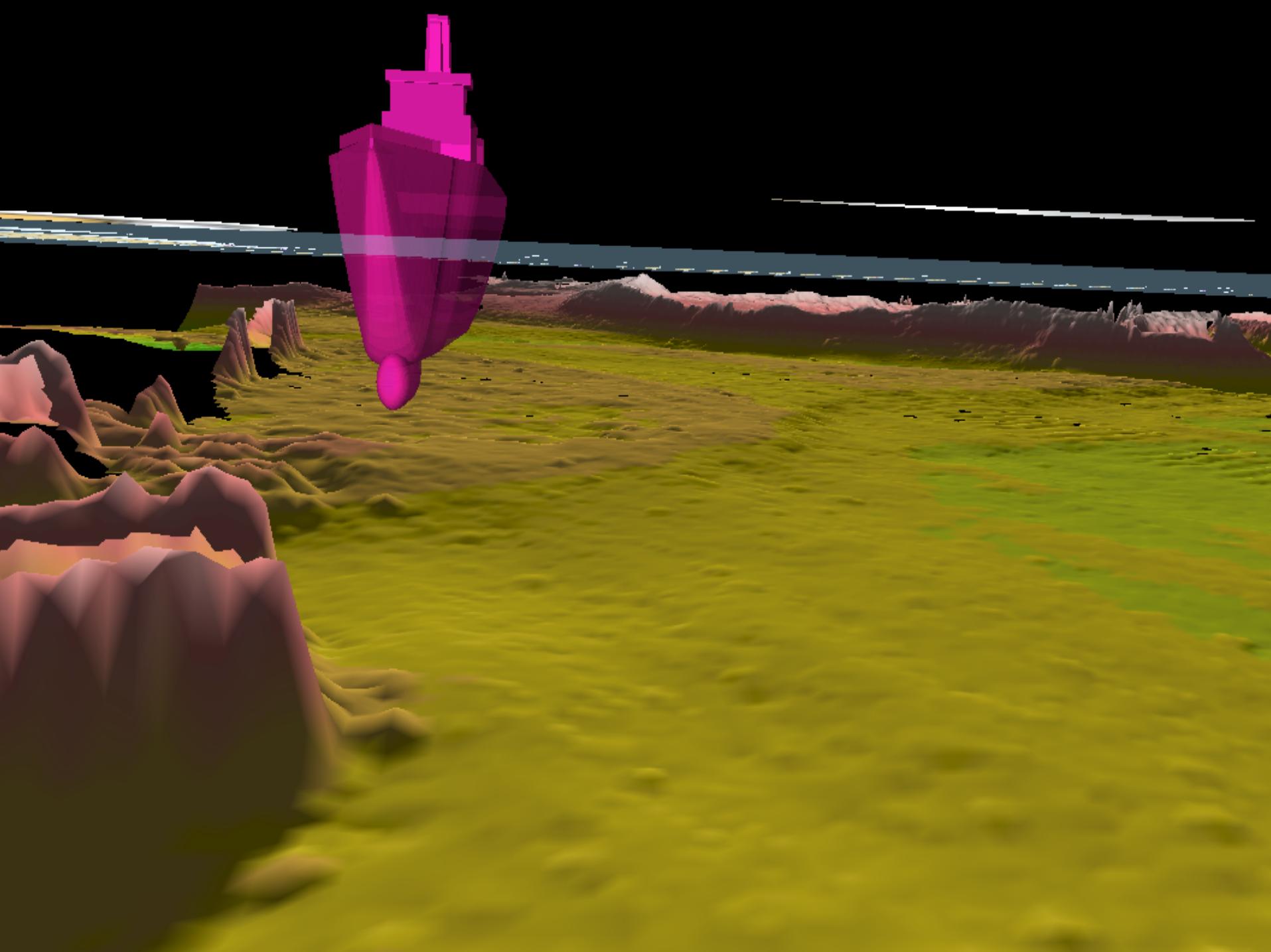






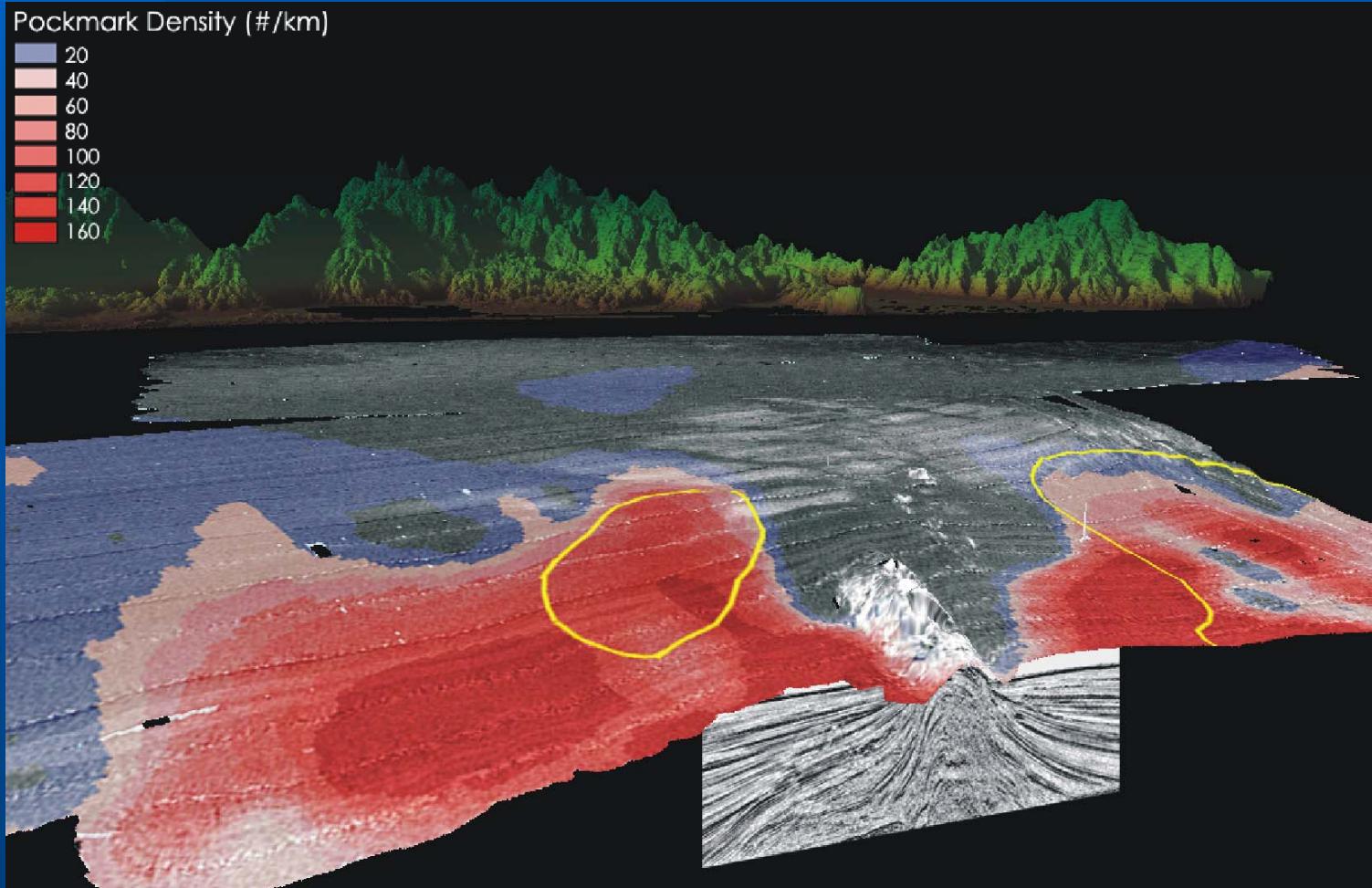








Interactive 3-D GIS to better understand relationship between backscatter anomalies and gas

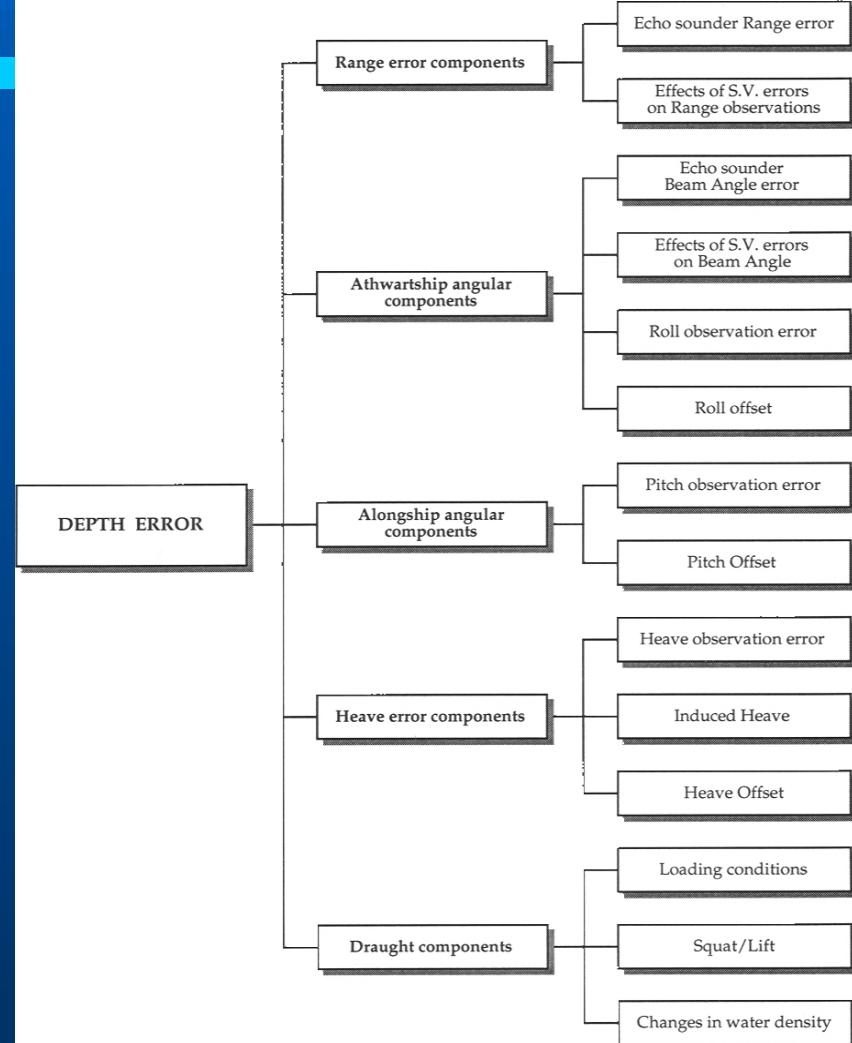




Multibeam Sonar Error Modeling



The Sources of Errors



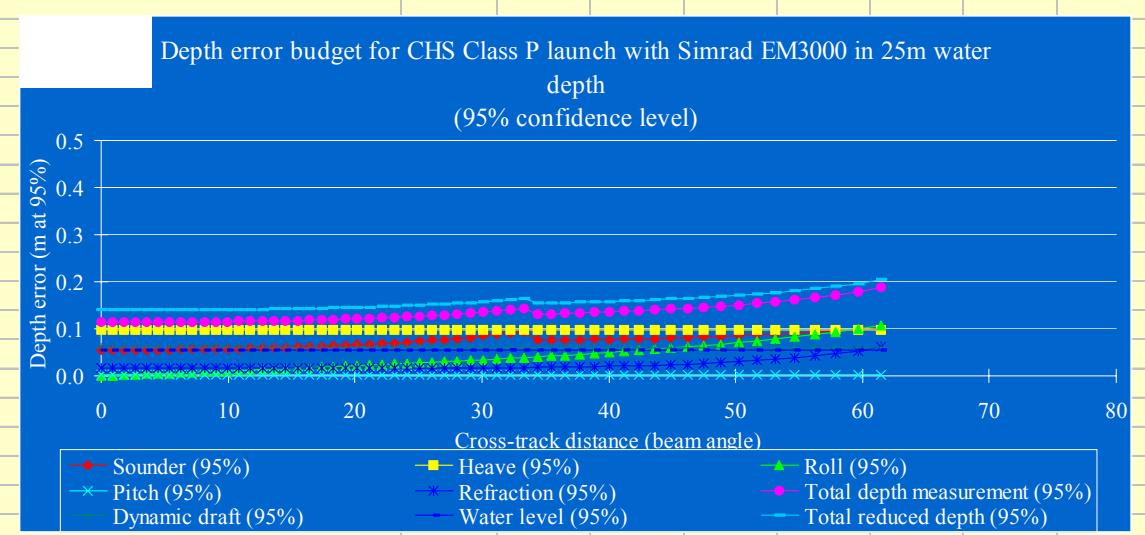
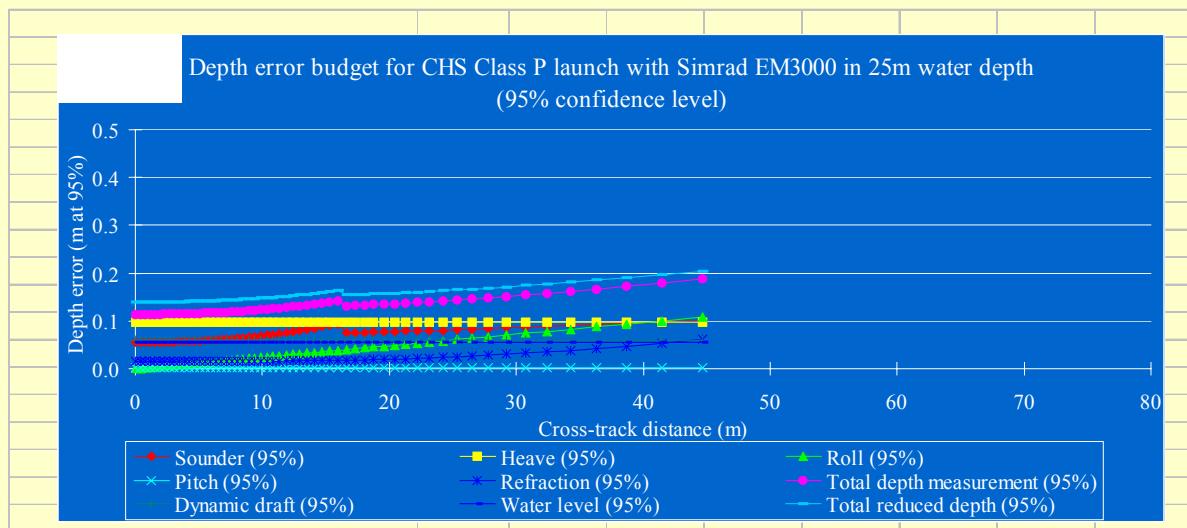
ERROR ESTIMATION

Vessel Parameters

<i>All errors at 68% confidence unless otherwise noted</i>	
General	
Vessel type	P Class Launch
Max. boat's speed (knots)	13.0
Speed error (m/s)	0.2
Heave sensor	POS MV 320
Roll sensor	POS MV 320
Pitch sensor	POS MV 320
Heading sensor/gyro	POS MV 320
Positioning system	DGPS
Velocimeter	SVP-16
<i>Sensor coordinate offsets</i>	
<i>(based on CSS Revision 1)</i>	
Positioning X (m)	0.219
Positioning Y (m)	-0.117
Positioning Z (m)	4.503
VRU X (m)	-0.242
VRU Y (m)	0.004
VRU Z (m)	0.464
Transducer X (m)	0.000
Transducer Y (m)	0.000
Transducer Z (m)	0.000
Transducer Draft (m)	0.700

Environmental Parameters

All error estimates at 68% confidence	
Water depth (m)	25
Water level error (m)	0.02
Spatial tide prediction error (m)	0.02
Sound speed (m/s)	1536.0
Sound speed meas. error (m/s)	0.50
Spatial variation (m/s)	0.1
Temporal variation (m/s)	0.1
Swell (p-p)	0.1
Roll angle (deg)	2.0
Pitch angle (deg)	2.0
Seafloor slope (deg)	0.0

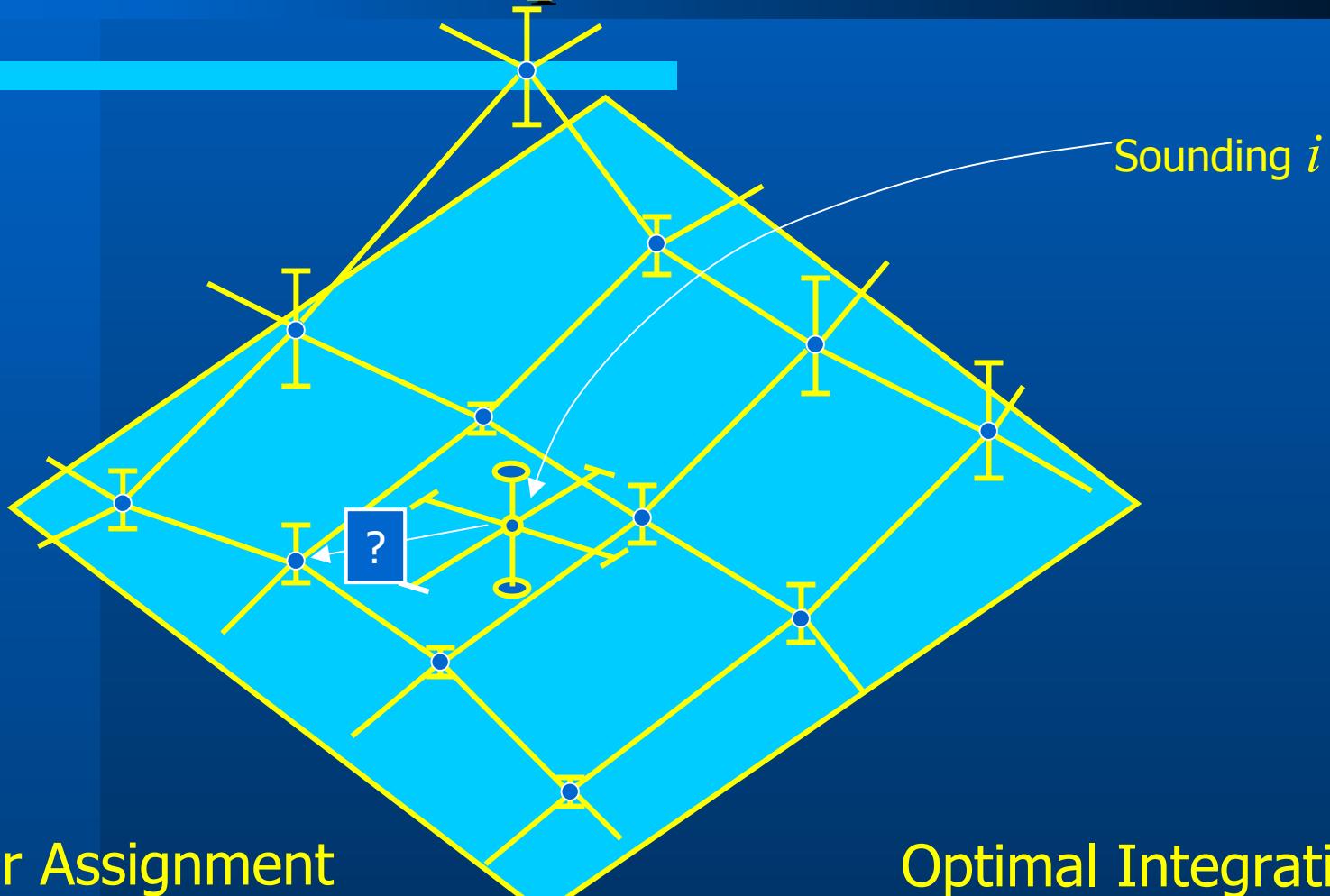




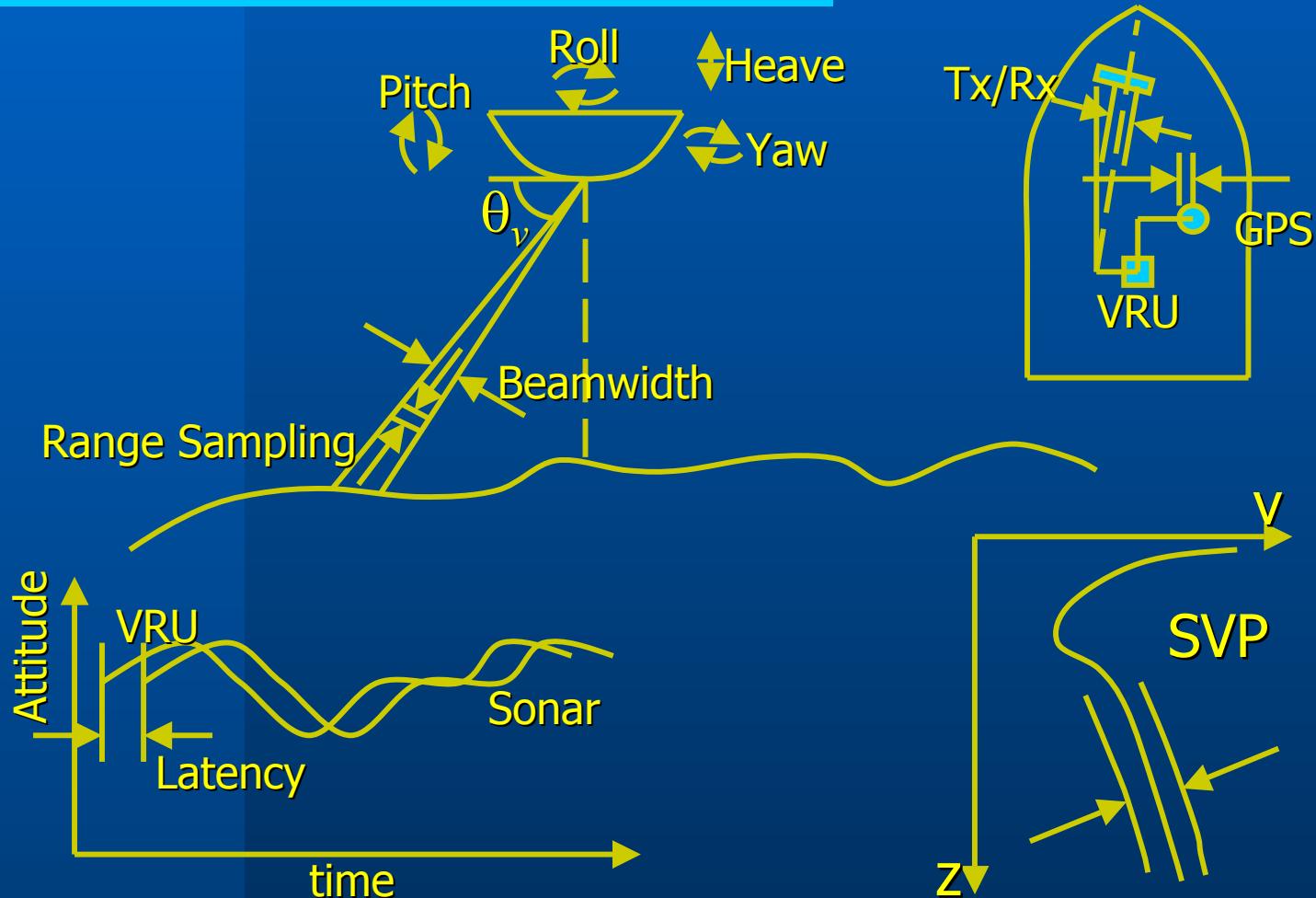
CUBE Surface Estimation

- **Attempts to answer the dual questions:**
 - What is the depth at location (x,y)?
 - How confident are we about the estimate?
- **Constructs graph of nodes with:**
 - Estimate of depth
 - Estimate of uncertainty of depth reported
 - “Other” properties (vectorized surface)
- **Incorporates depths recursively**
 - Low memory footprint
 - Continuous “current best estimate”
- **Robustness by integrating multiple estimates**

Recursive Update



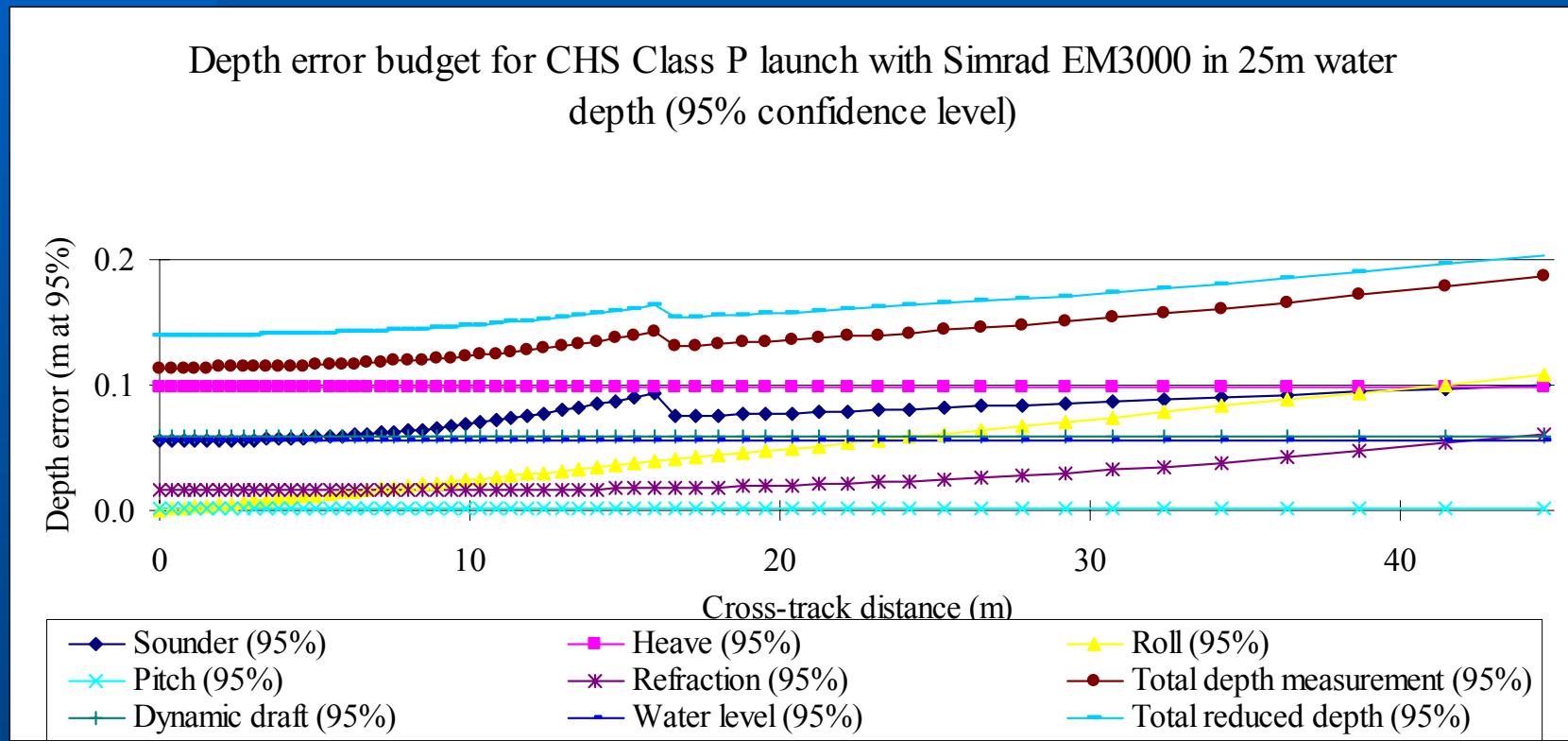
Error Assignment



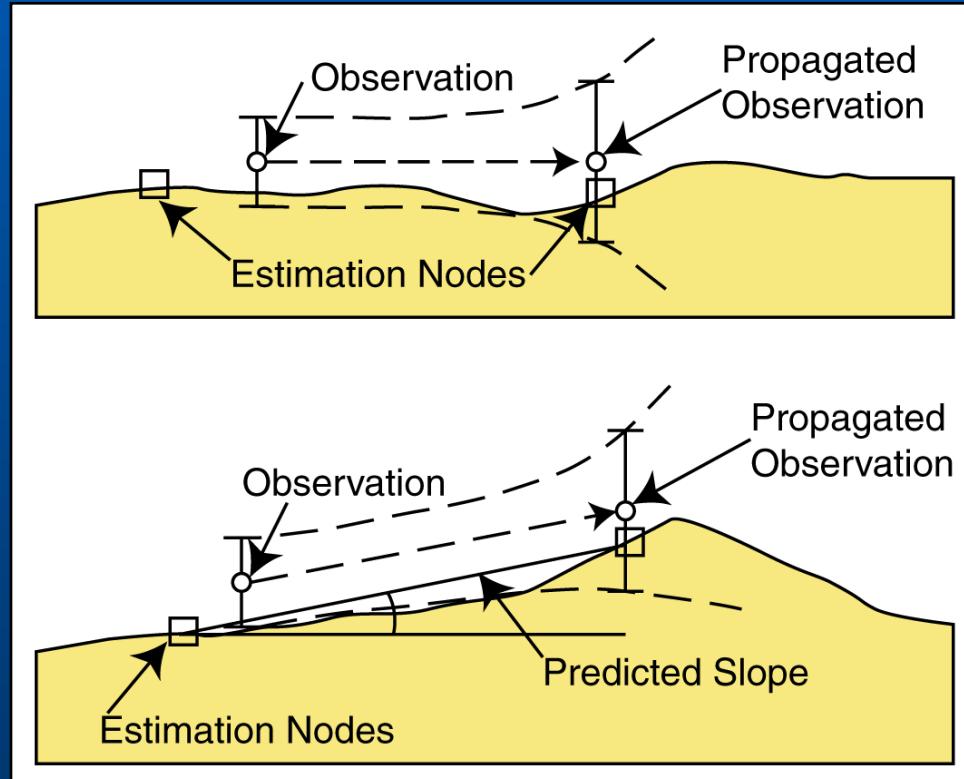


Error Assignment

Depth error budget for CHS Class P launch with Simrad EM3000 in 25m water depth (95% confidence level)



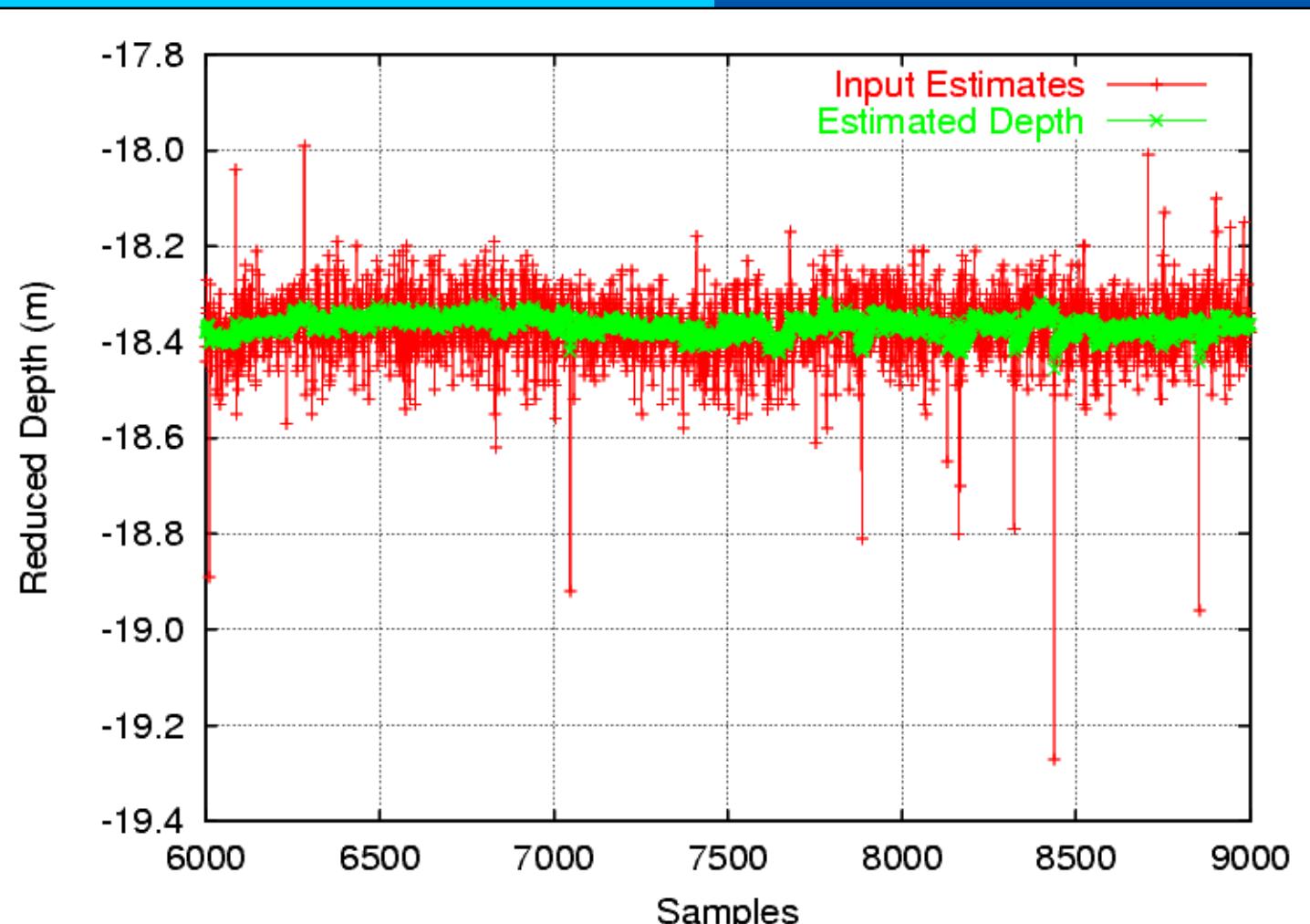
Estimate & Uncertainty Propagation



- Balance data fidelity with safety
- Application specific

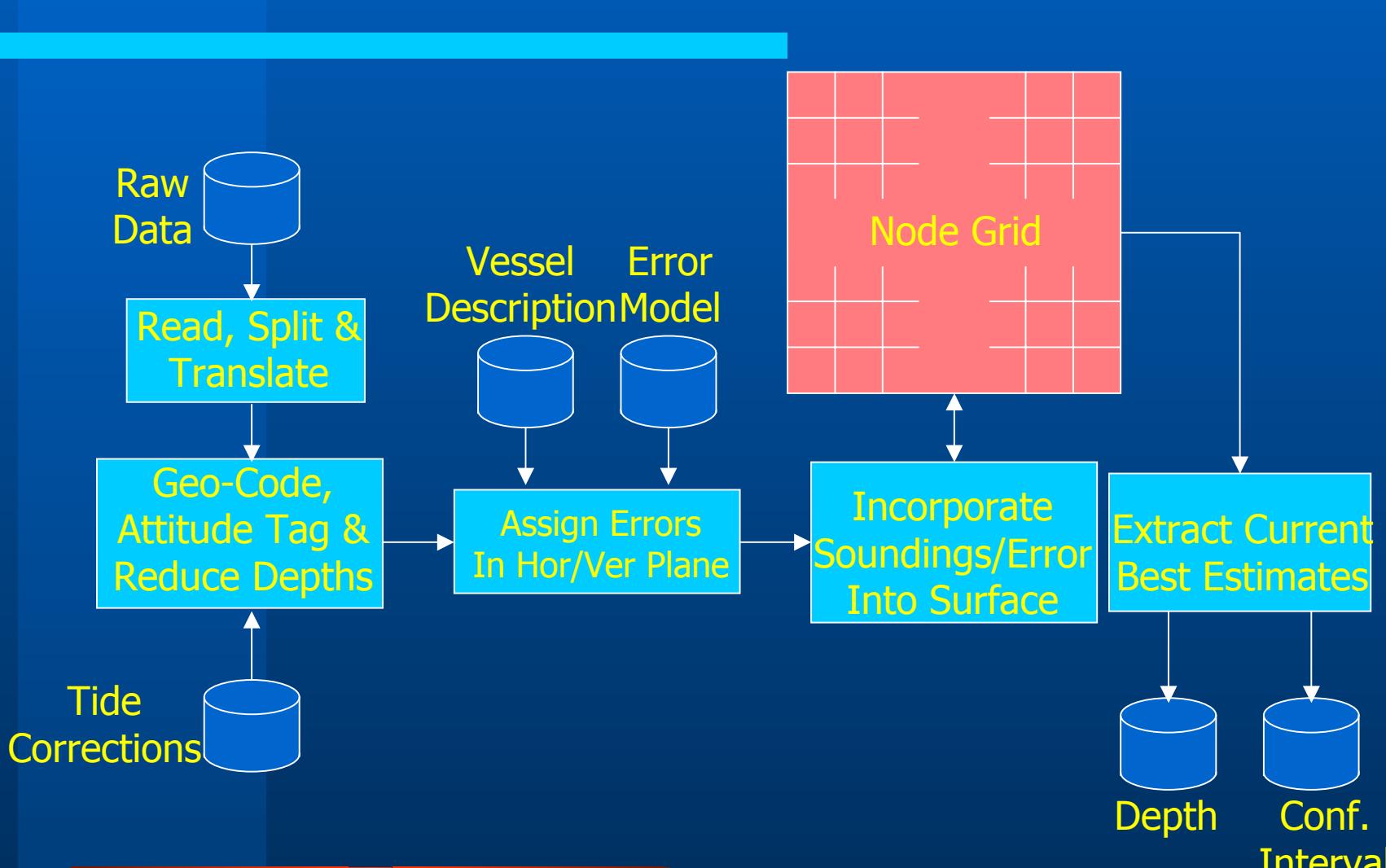


Data Assimilation



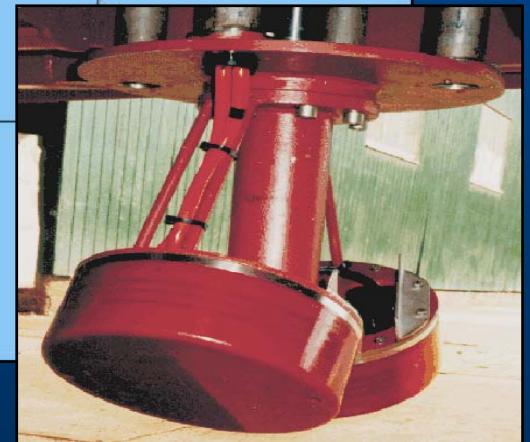


Processing Chain





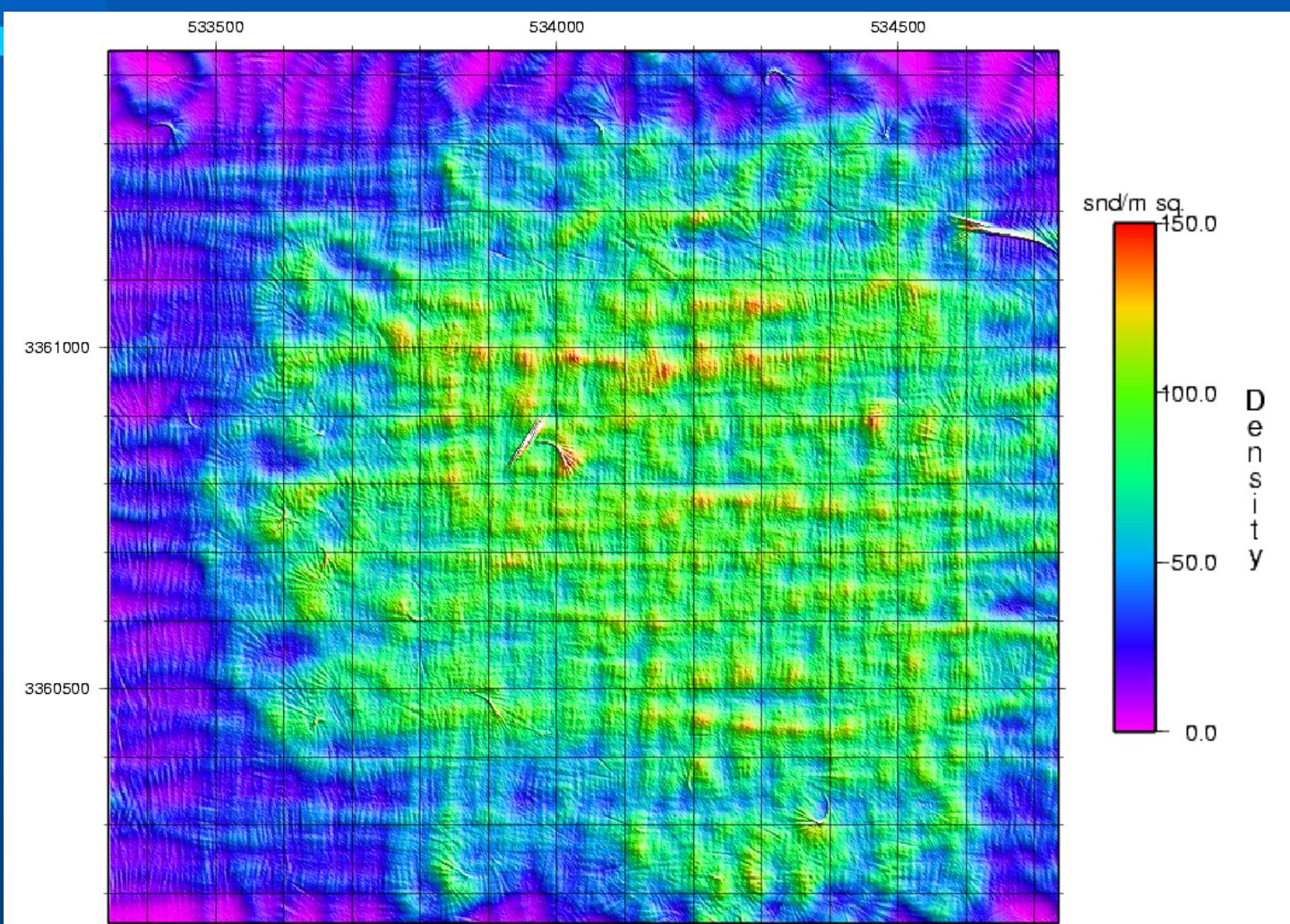
SAX'99 Dataset Location



Simrad EM3000 Shallow Water Multi-beam

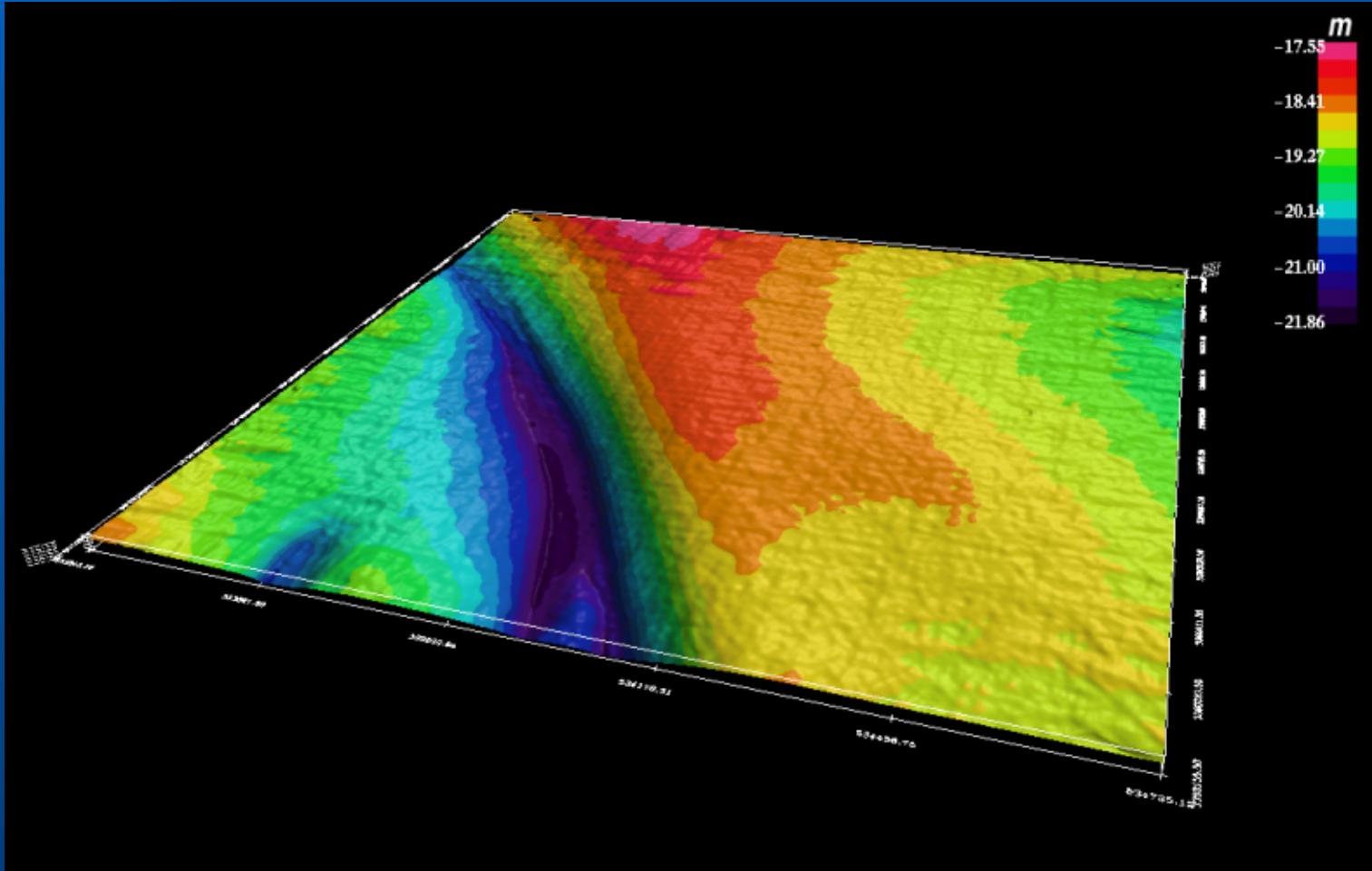


SAX'99 Dataset Density



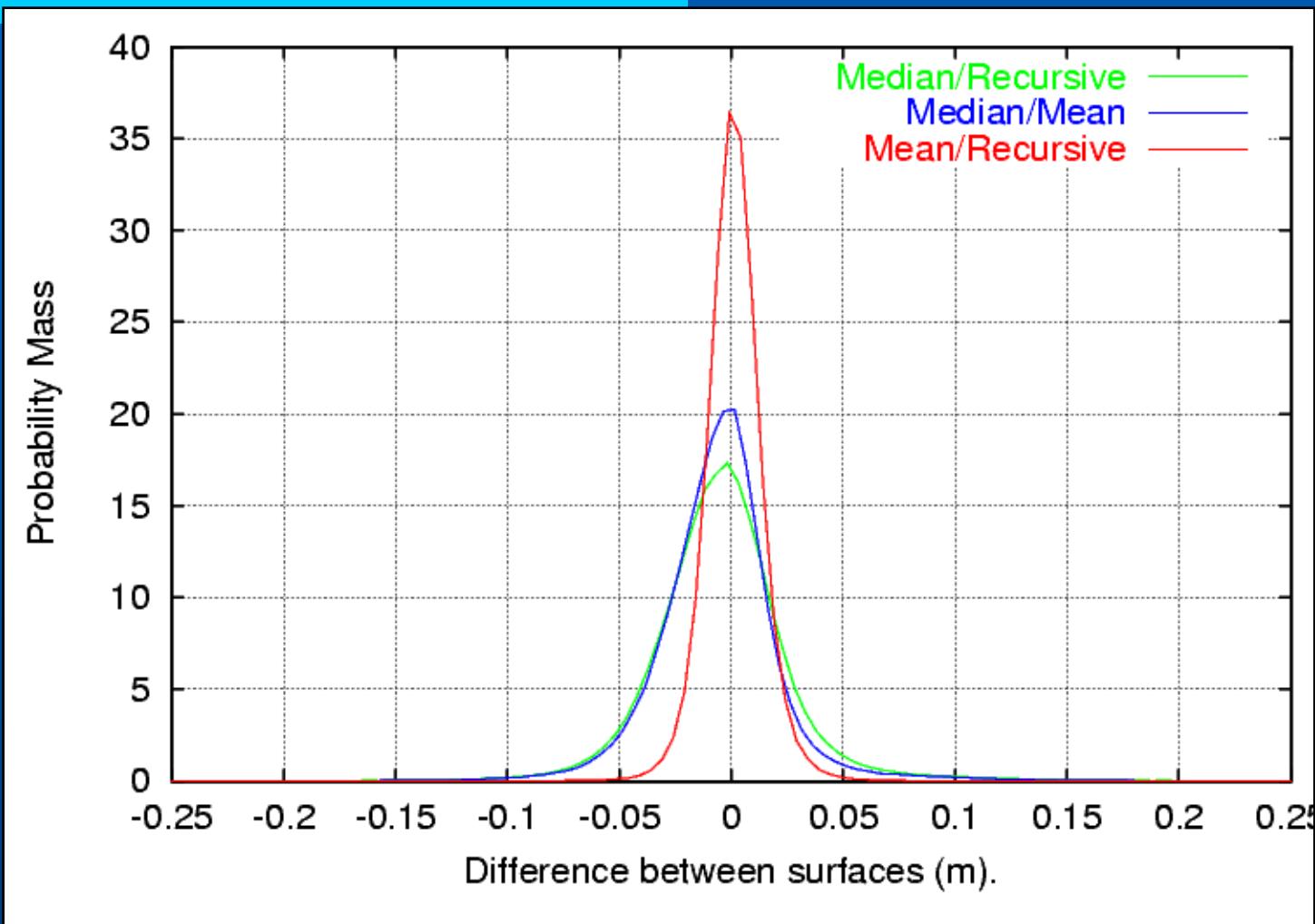


Bathymetry Surface



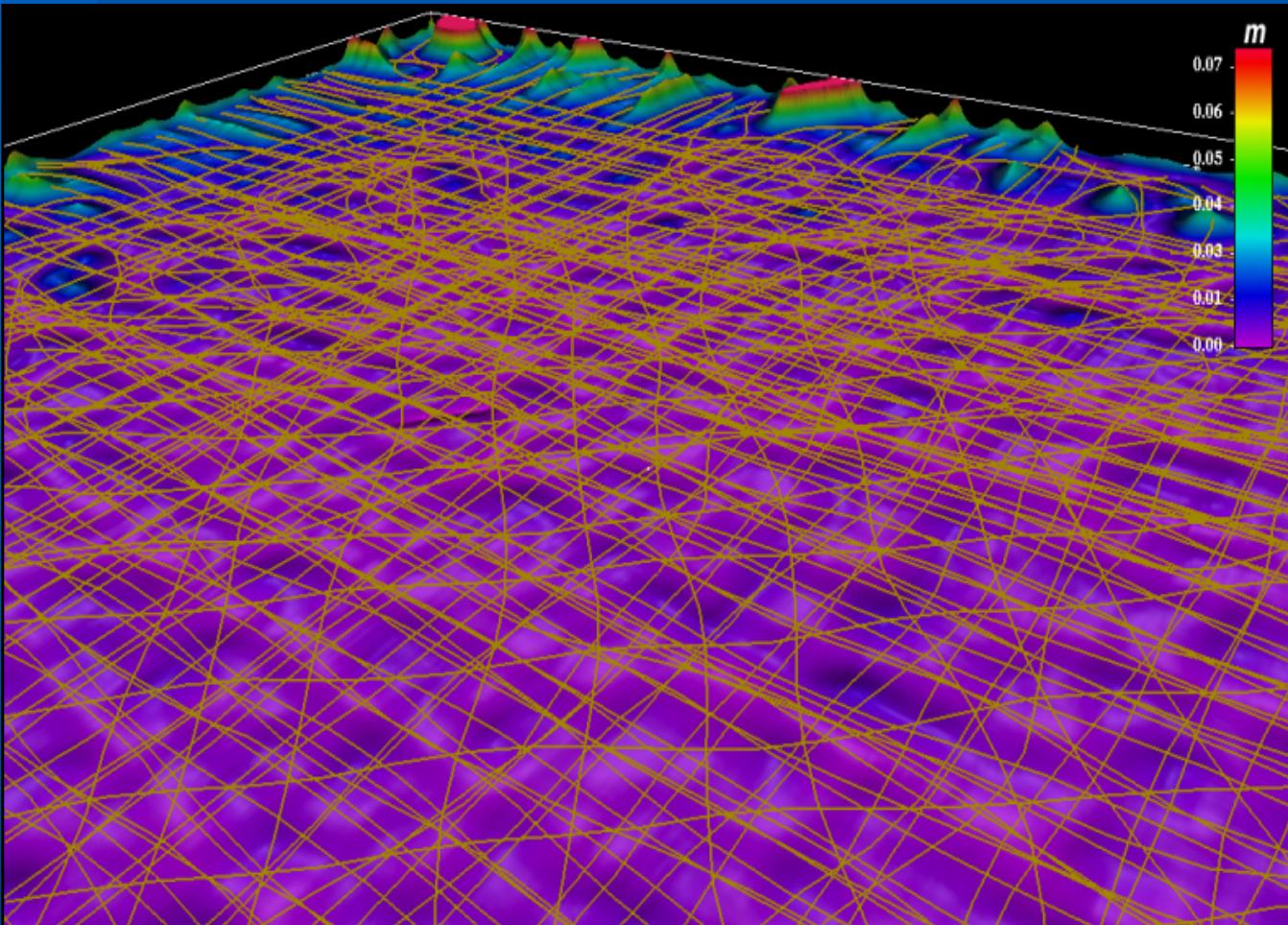


Surface Comparison



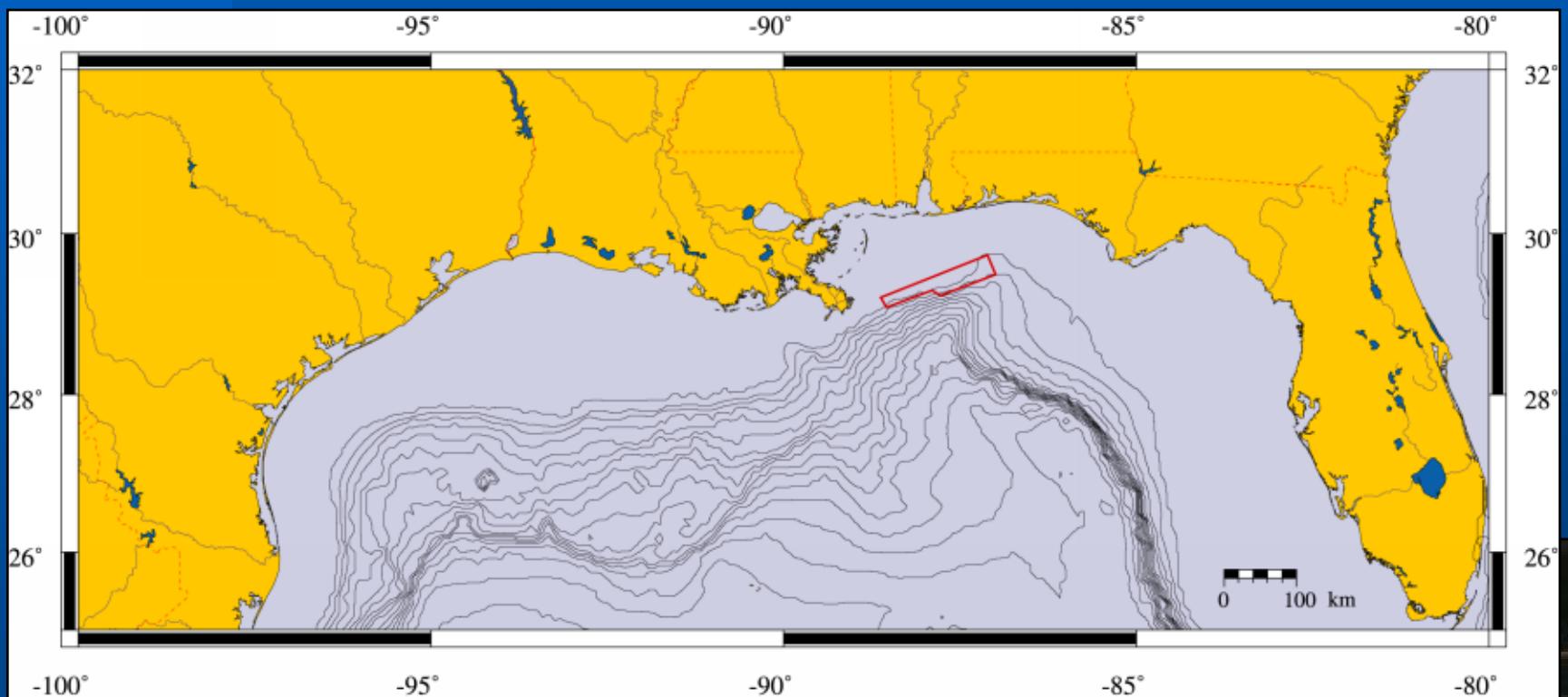


Uncertainty Surface





Example: USGS Pinnacles Cruise

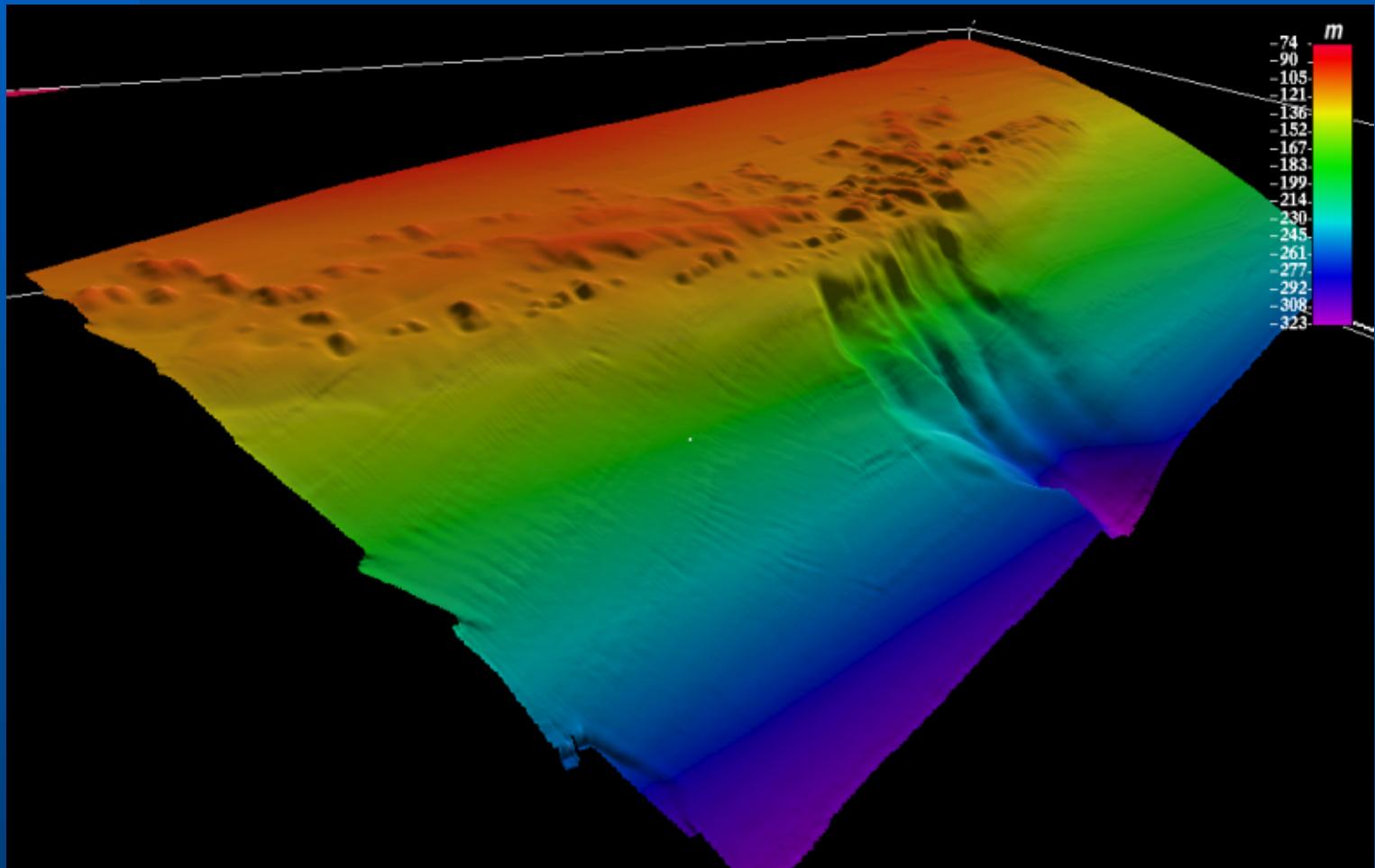


EM1002 Intermediate Depth Multi-beam



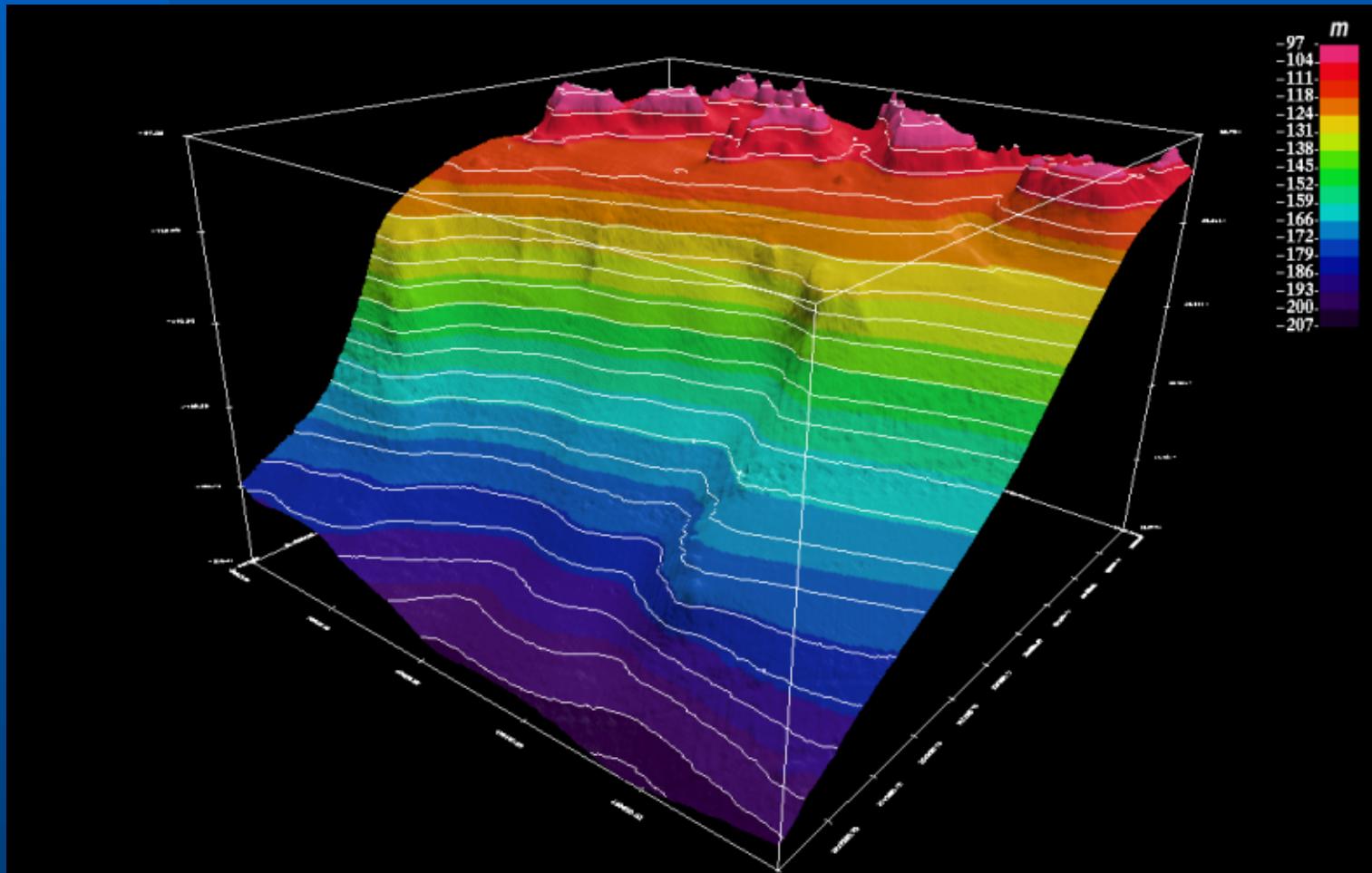


Bathymetry at 20m Resolution



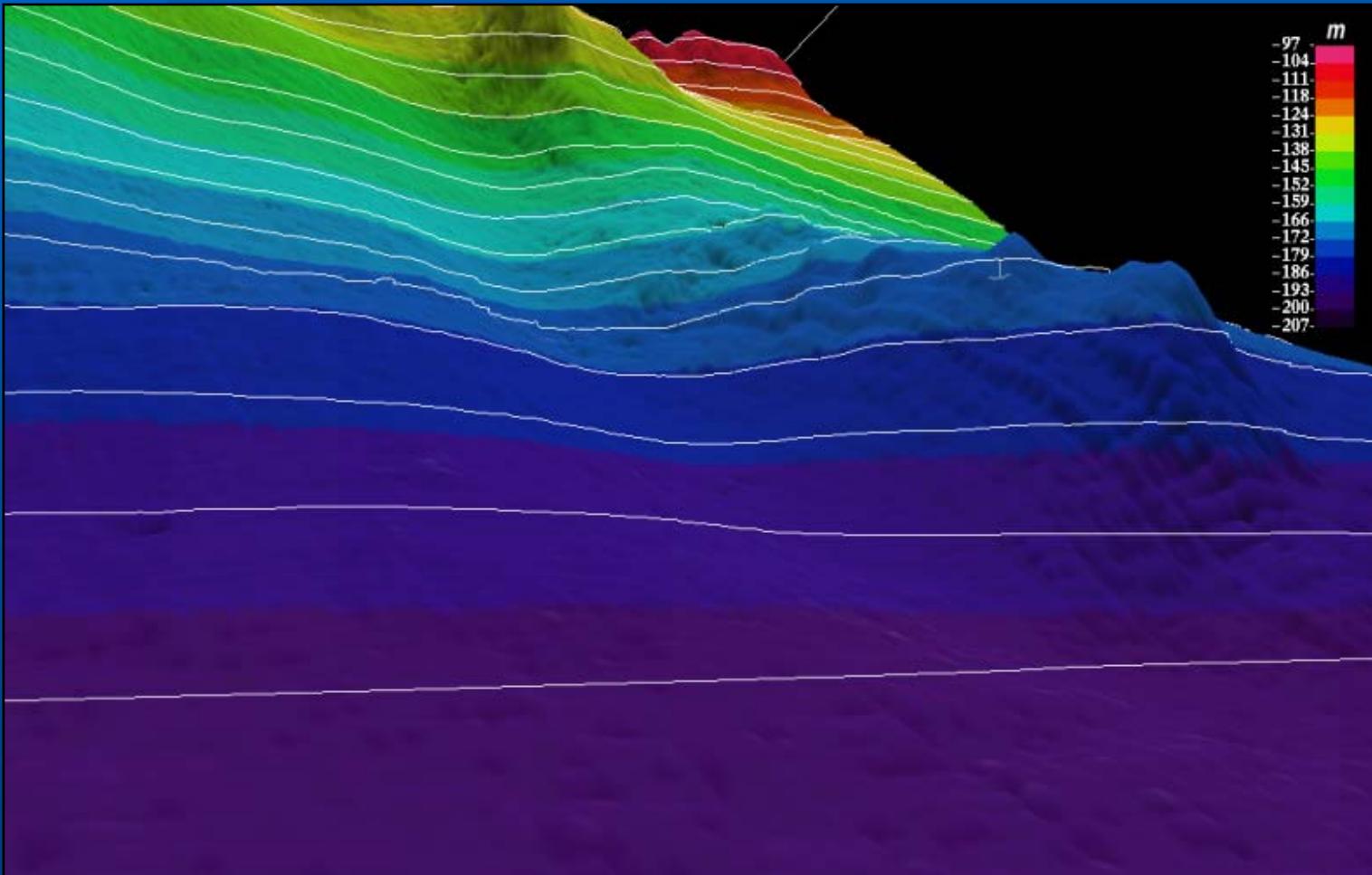


Bathymetry at 4m Resolution



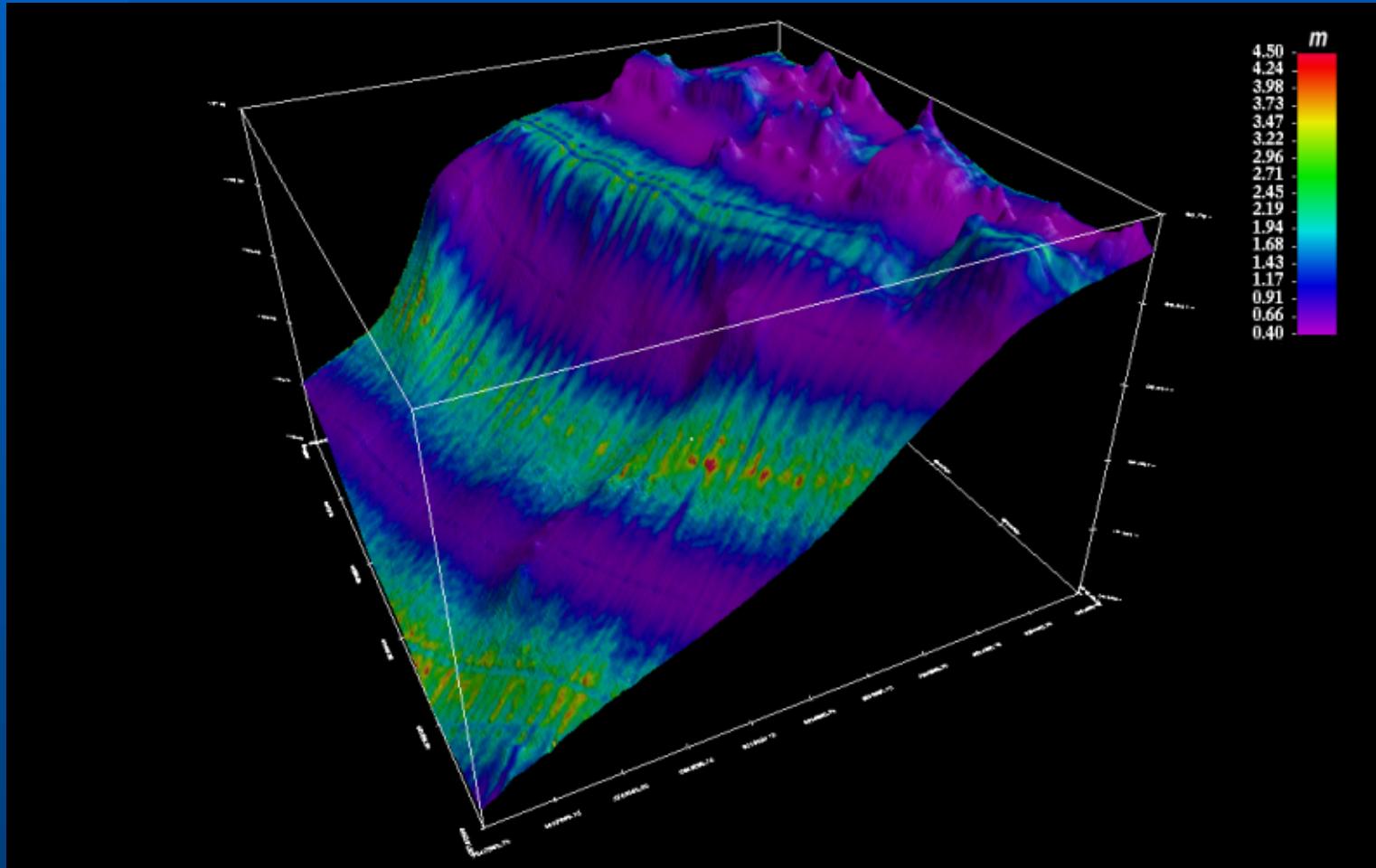


Bathymetry at 4m Resolution





Combined Bathymetry & Error

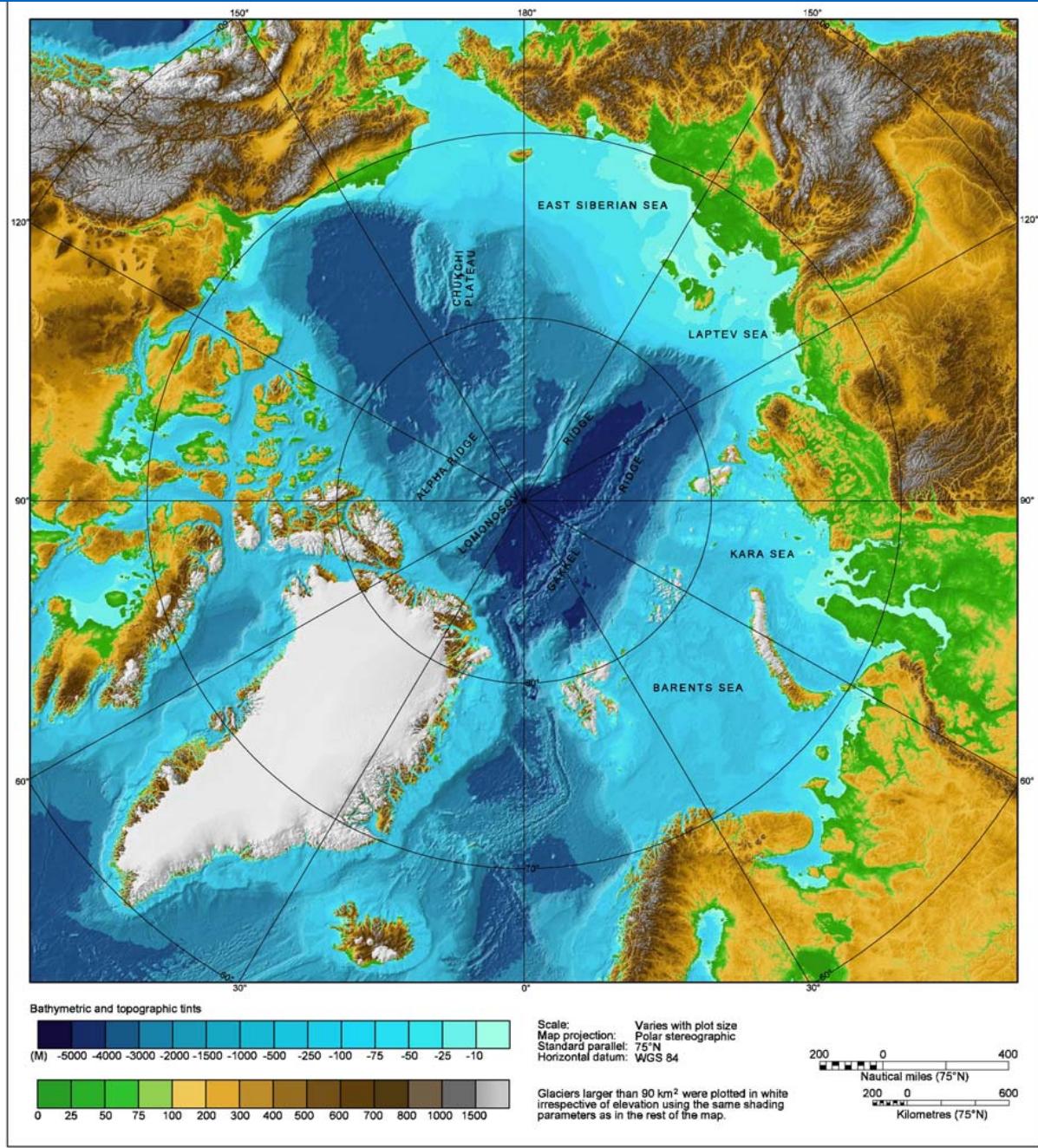


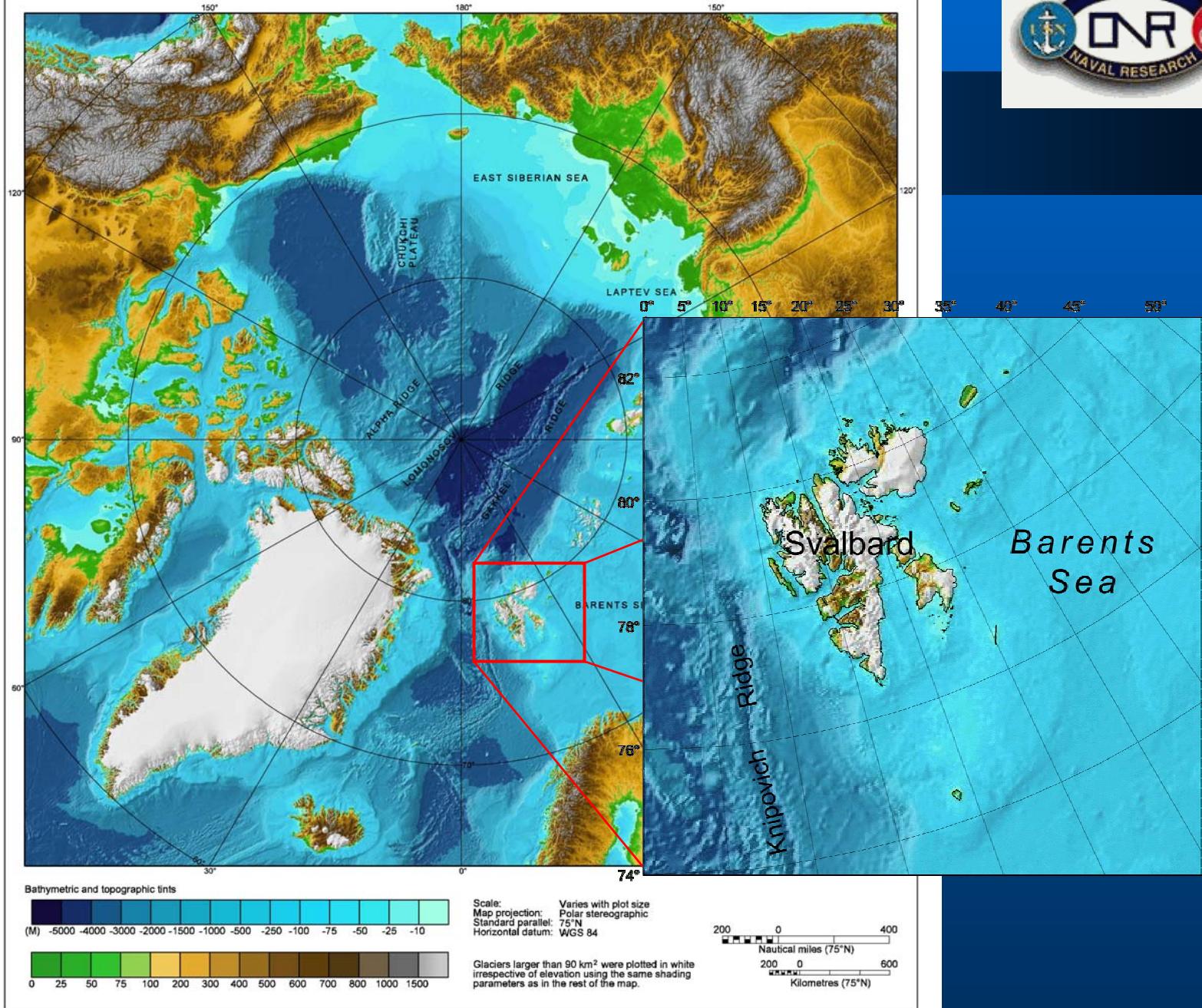


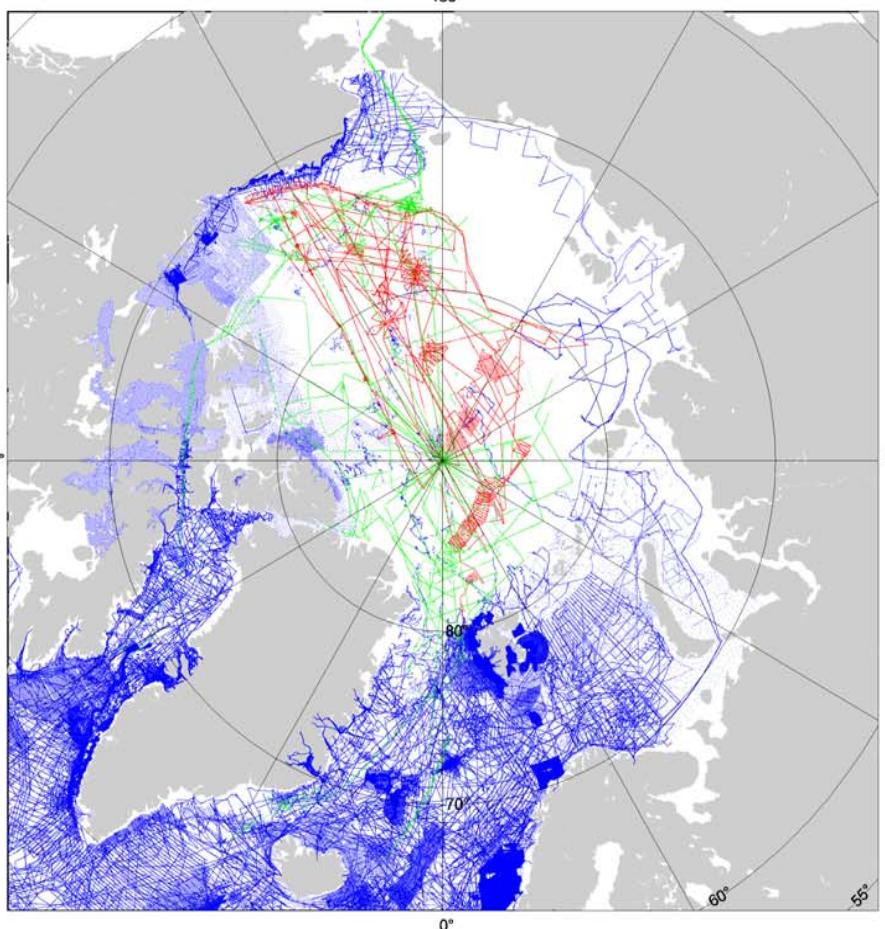
IBCAO Error Modeling

“Regional bathymetric compilations of the world oceans that are based on a mixture of historic and contemporary data sets will remain the standard for the foreseeable future”

“Our compilations have traditionally treated each sounding with equal weight”







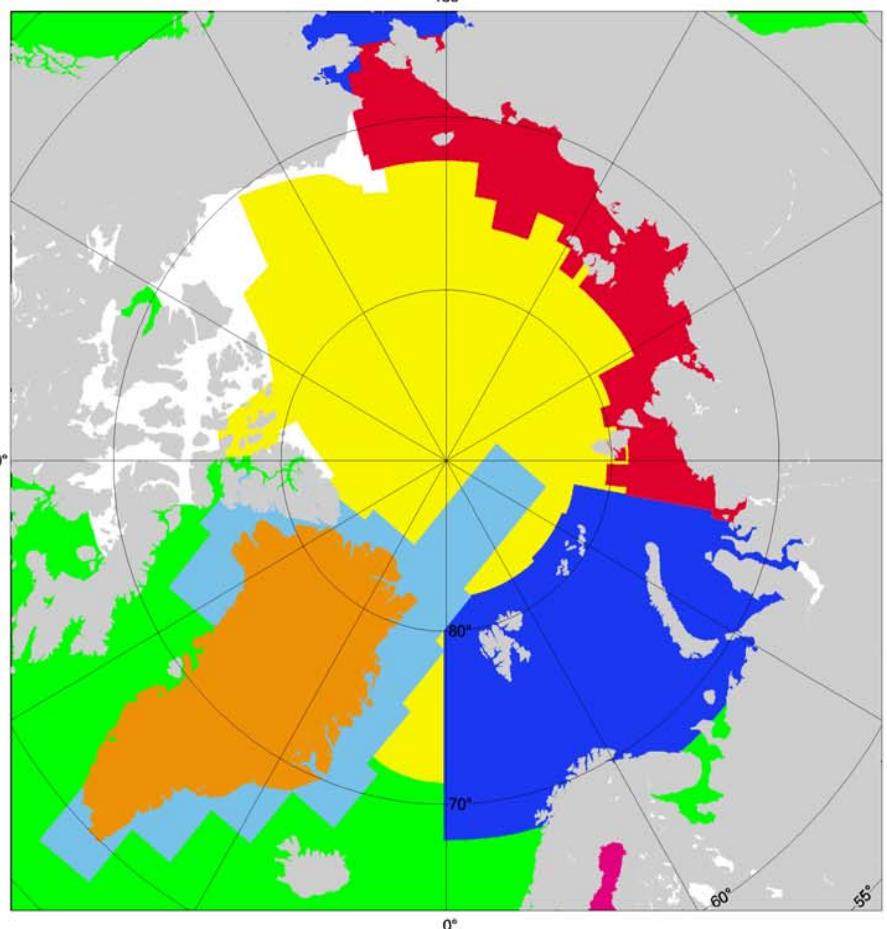
● ● ● ●
US and British Royal Navy nuclear submarine cruises (1958 - 1988).

● ● ● ●
Soundings collected by nuclear submarines during the SCICEX program (1993-1999).

● ● ● ●
Soundings collected by surface vessels primarily obtained from four archives:

- (1) the US National Geophysical Data Center (NGDC)
- (2) the US Naval Research Laboratory (NRL)
- (3) the Canadian Hydrographic Service (CHS)
- (4) the Royal Danish Administration of Navigation and Hydrography (RDANH)

Recent acquisitions provided by agencies that mobilized missions aboard the Swedish icebreaker Oden (1991, 1996) and the German research vessel Polarstern (1990, 1994, 1995, 1997) are also marked in blue.



● ● ● ●
Contours drawn during this present work in order to facilitate the computer gridding.

● ● ● ●
Charts published by the US Naval Research Laboratory (Perry et al., 1985; Cherkis et al., 1991; Matishov et al., 1995).

● ● ● ●
Navigational charts published by the Russian Federation's Head Department of Navigation and Oceanography (HDNO).

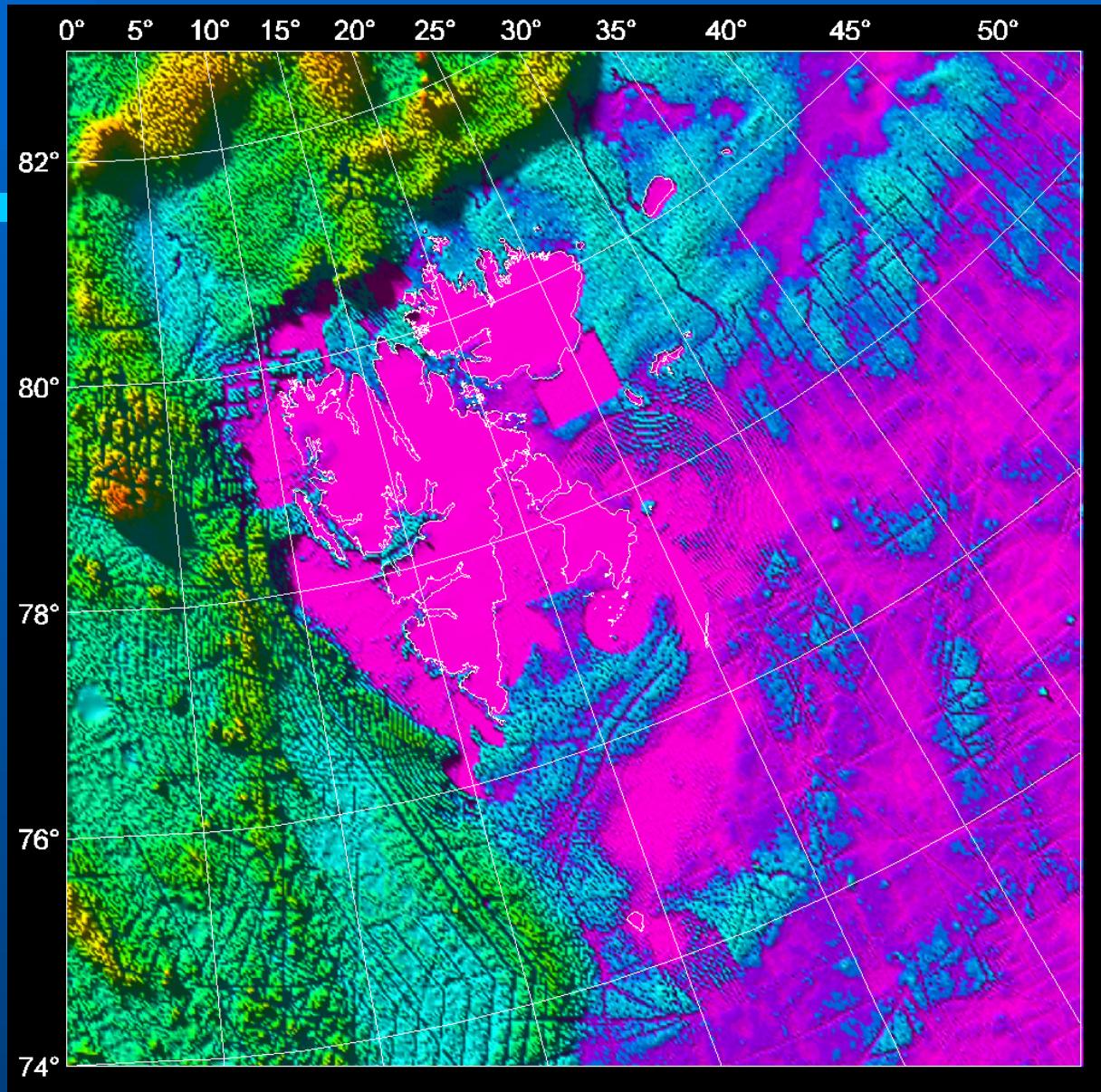
● ● ● ●
Contours retrieved from GEBCO Digital Atlas.

● ● ● ●
Newly-published Russian map (Head Dep. of Navigation and Oceanography et al., 1999).

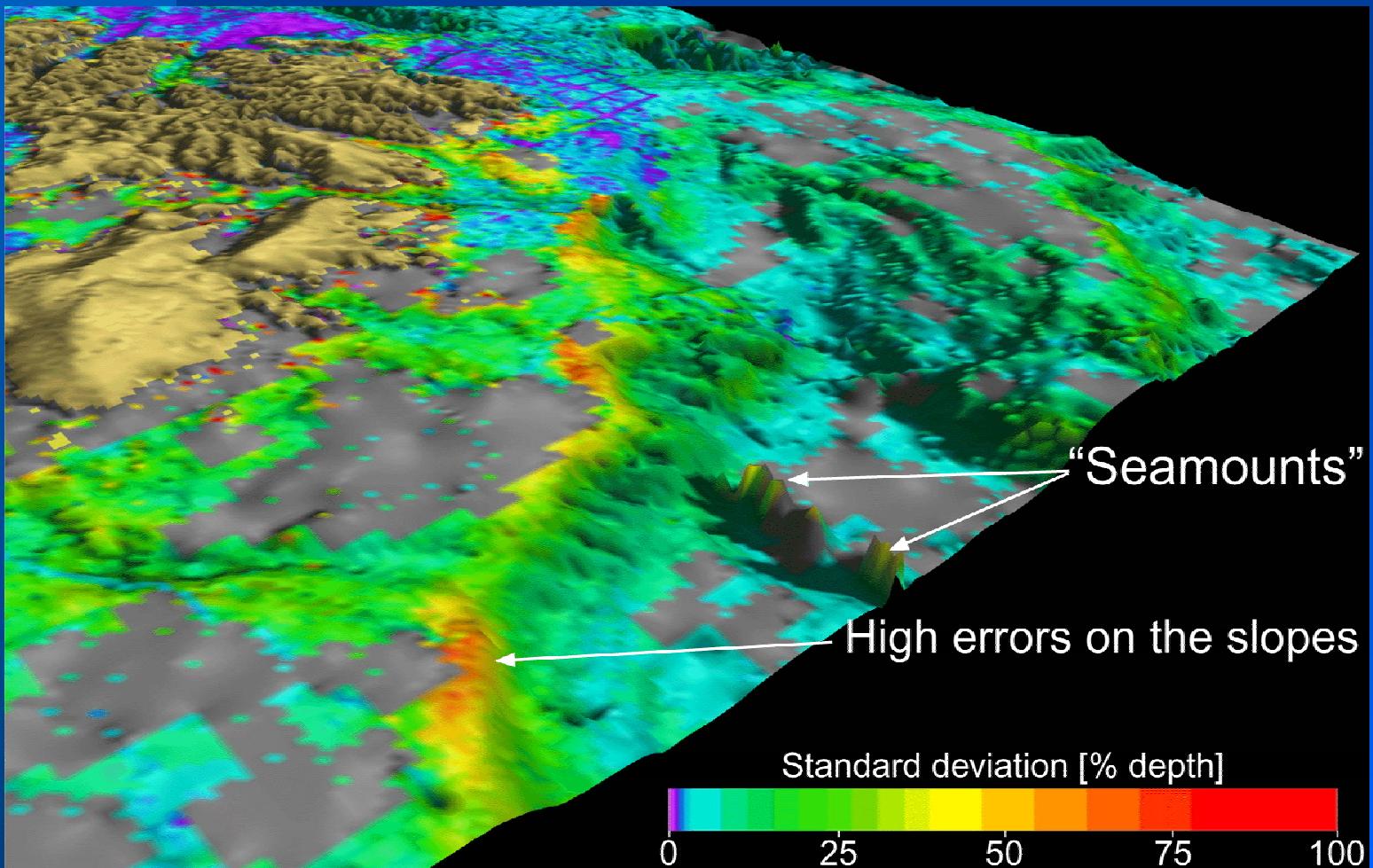
● ● ● ●
Greenland DTM developed by KMS, the Danish Cadaster and Mapping Agency (Ekholm, 1996).

● ● ● ●
Bathymetry in the Gulf of Bothnia was derived from a digital grid compiled by Seifert and Kayser (1995).

● ● ● ●
GTOPO30 topographic model (U.S. Geological Survey, 1997).



VISUALIZING ERRORS IN 3D





Visualization

